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THE MINK RIVER — A FRESHWATER ESTUARY

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Abstract

The Mink River Estuary is one of the few remaining natural wetlands along the Lake Michigan coastal zone. The river flows through a bedrock valley across the Door Co., Wisconsin, peninsula. Surficial materials forming its watershed are glacial and post-glacial, mainly shoreline material placed during higher levels of Lake Michigan.

The dynamics of Lake Michigan play an important role in the control of wetland plant communities. Most expand and contract as the lake level falls and rises over the long-term. Lake seiches cause the water in the wetlands to flow upstream and downstream in both a daily and hourly cycle, generating a persistent gradient between the alkaline headwater springs and more neutral lake.

Land use adjacent to the river has changed little since presettlement, although the upland forest in the surrounding watershed has been largely replaced by farm fields. The estuary consists of several vegetation types. The deep marsh and shallow marsh types are inhabited by communities of few species, owing to disturbance by long-term changes in lake water level. The wet meadow, shrub carr, and lowland forest types are more diverse, largely because they are more protected from extreme water level change by elevation and, in the case of wet meadow species, by the development of hummocks by *Carex stricta.* Peak above- and below-ground biomass found in herbaceous wetland communities in 1981 are presented. Perennial species peak in August, while annuals peak in September; most below-ground accumulation peaks in September.

Introduction

The U.S. shoreline of the Great Lakes is nearly 4000 miles in length. Wetlands occupy only a small proportion of the coastal region; 1370 coastal wetlands, comprising an area of 466 square miles, have been identified (Herdendorf et al. 1981). Approximately 30% of U.S. Great Lake wetlands occur adjacent to Lake Michigan. Many rivers that flow into the Great Lakes were once associated with wetland areas; most of these are now either heavily disturbed or have been destroyed by urban development. Curtis did not recognize Great Lakes coastal wetlands as a community type in his *Vegetation of Wisconsin* (1959). In recent years, there have been a number of descriptive studies of wetlands along the Lower Great Lakes (Williamson 1979, Brant and Herdendorf 1972, Fahselt 1981, Hanink 1979, Herdendorf et al. 1981, Jaworski and Raphael 1976, Mudroch 1981, Geis, 1985, Geis and Kee 1977, Stuckey 1971, 1975, LeMay and Mulamoottil 1980, Farney and Bookhout 1982, and Ruta 1981). The few studies of Wisconsin coastal wetlands deal primarily with those along Green Bay (Bosley 1976, 1978, Harris et al. 1977, Howlett 1974, and Roznik 1978).

The Mink River supports one of the best of the remaining Lake Michigan coastal wetlands. Located near the tip of the Wisconsin Door County Peninsula, the Mink River flows southeastward into

Fig. 1. Location of the Mink River on the Door County, Wisconsin, peninsula.

Rowley Bay of Lake Michigan (Figure 1). The watershed lies in Liberty Grove Township (T32N, R28 and 29E). In this paper, I will describe the physical setting of the Mink River wetlands and the vegetation types present and their dynamic relationship with Lake Michigan.

Topography and Geology

Rowley Bay and the Mink River lie in a bedrock valley that extends across the Door peninsula from Green Bay to Lake Michigan (Kowalke 1946). During the Algonquin period, when the level of Lake Michigan was higher, the valley formed a strait connecting Green Bay to Lake Michigan from Ellison Bay to Rowley Bay. The underlying bedrock is Silurian Niagara dolomite; as elsewhere in the Door Peninsula, this formation dips to the southeast, and forms the primary aquifer. A wide portion of the river, "Rogers Lake," may represent a natural depression in the bedrock or an area eroded by the channel before descending into Lake Michigan. Bedrock is within four feet of the surface near Ellison Bay and outcrops in the upland around the Mink River. The upland is covered by Pleistocene drift and shoreline deposits. Most of the region was inundated by post-Pleistocene stages of Lake Michigan, resulting in permeable deposits of sand and gravel along the west side of the river (Sherrill 1978). Thwaites and Bertrand (1957) and Kowalke (1946) suggested that the uplands to the northeast and southwest of the river were islands in Lake Algonquin, a higher stage of Lake Michigan. A shoreline formed by Glacial Lake Algonquin (11,000-12,000 yr BP) has been found along Rowley Bay in Newport State Park at approximately 75 feet above present lake level. A Glacial Lake Nipissing shoreline (3,500-6,000 yr BP) occurs 21 feet above present level (Frelich 1979, Dorr and Eschmann 1977). The ancient beach ridges evident in the landscape around Rowley Bay were Lake Nipissing beaches. The marsh along the Mink River is underlain by alluvial fine sand, silt and clay and organic material.

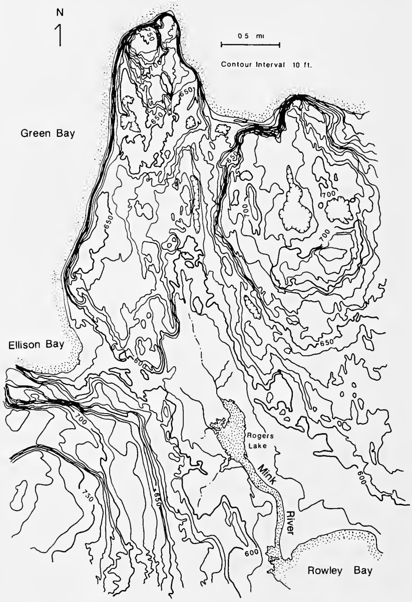

Fig. 2. Topography of the area surrounding the Mink River. Contour interval is 10 feet. Stippled areas represent open water and lakeshore boundaries.

These fine grey sediments and the sandy soils of the surrounding area were probably deposited during this post-glacial lake stage. Declining lake level and land rebound have raised the old beaches and also separated the Mink River watershed from Green Bay (Figure 2).

Hydrology

Hydrologic aspects of the watershed are the most important factors contributing to the character of the Mink River wetland. There are three primary sources of water: precipitation, groundwater springs, and Lake Michigan. Surface runoff from the small watershed is limited by lowland forest vegetation.

Springs located in the lowland forest surrounding the marsh discharge into the wetland creeks throughout the year. Springs also emerge within the wetland; these have been observed as open pools in February surrounded by the snow-covered marsh. Weathered limestone is exposed at the bottom of the headwater springs, attesting to their origin in the bedrock aquifer.

The channels connecting the headwater springs to the river appear well entrenched in the substrate. A review of past aerial photographs (1938, 1952, 1962, 1967, 1974, 1978) indicates that location of the channels has not changed appreciably in almost 50 years. Sherrill (1978) suggested that the drift overlying the bedrock around and under the Mink River is shallow. The main channel of the Mink River forms a distinct and apparently unchanging bend as it flows near an upland bedrock knoll. Although most of the depression containing the river and wetland appears to have been filled by lake sediments and beach deposits, the channel forms suggest bedrock control of the major channels.

Rainfall is moderate; the NOAA station on nearby Washington Island records an average annual precipitation of 29 inches. Approximately half of this amount falls during the growing season.

Precipitation and spring flow vary little from year to year. However, Lake Michigan plays a dominant role in wetland dynamics. The level of the lake has varied widely in historic time (Figure 3). Aerial photographs

Fig. 3. Mean annual level of Lake Michigan, 1935-1981 (from N.O.A.A. 1981).

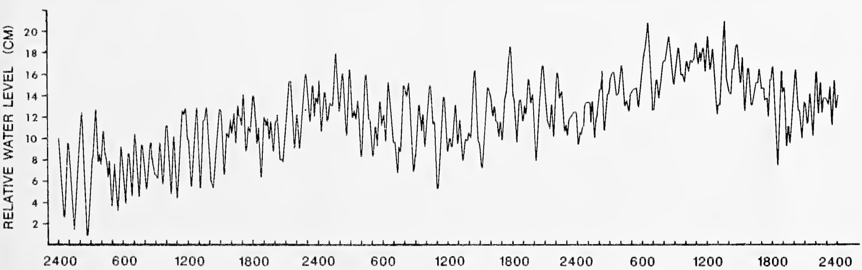

Fig. 4. Measurement of water level fluctuation in one of the headwater creeks, approximately 100 meters from a bedrock spring, taken between May 21-23, 1983. While the amplitude varies, the period is constant throughout the ice-free season.

taken since 1938 show that during periods of high lake levels, the open water area of the river and marsh increased along the entire length of the river. In alternating periods when the lake level was low, the wetland communities expanded into the open water.

Seiche activity originating in the lake results in water moving upstream and then downstream daily; superimposed is another mode in which water moves up and down the river in approximately an hourly cycle. An example of seiche activity is shown in Figure 4; this measurement was made with a water level recorder located upstream of Rogers Lake in one of the headwater creeks. Fluctuations at the mouth of the River are typically between 10 an 30 cm in magnitude, and occasionally much larger following high winds. Both seiche modes cause the water to rise and fall throughout the wetland, throughout the ice-free season. This results in mixing between the highly alkaline water discharging from the headwater springs and the water from Lake Michigan that is driven upstream. Water samples have been collected during all ice-free seasons; an example of the chemical gradient found along the length of the Mink River is illustrated in Figure 5. Specific conductance and alkalinity range from 475 to 275 mmhos/cm and 260 to 110 mg/l respectively; this pattern is maintained from the time of ice-melt in spring through the time when the bay and river surfaces freeze in winter. Based on these seiche movements and the chemical gradient, the Mink River may be considered a true estuary.

Land Use

The Door Peninsula has had a relatively long history of human activity. Initially, Indian tribes moving up and down the lakeshore probably used the area around the Mink River for encampments. There was a more permanent village on the south side of the bay, but it is not clear whether this was a Winnebago or Potawotami tribe. Logging removed most of the upland forest cover during the late 1800's. White cedar in the lowland forest was also harvested for both lumber and cedar oil; an oil-distilling factory was located near Rowley Bay. There was

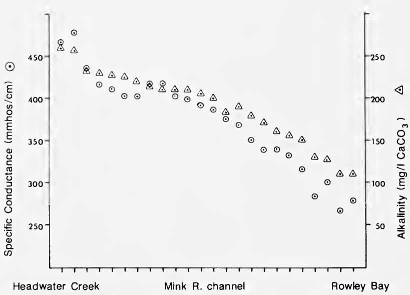

Fig. 5. Evidence of a chemical gradient along the Mink River channel. The X-axis is a series of sample stations along the length of the river, from a headwater spring and creek (left) through the river channel (center) to Rowley Bay (right). Specific conductance and alkalinity both decrease along the river.

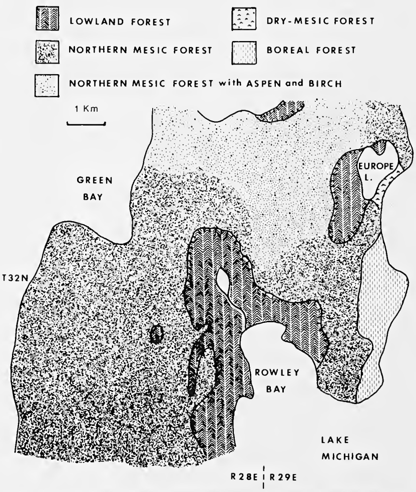

Fig. 6. A map of the presettlement forest in the area of the Mink River (derived from Findley, 1976 and personal communication). Emergent marsh is not mapped. Vegetation types follow Curtis (1959).

considerable land speculation during this period as well; much of the Mink River basin was platted and some lots sold, although no development occurred. Farms were cleared in portions of the Mink River watershed, as everywhere in the Door Peninsula (Holand, 1959). Thus, the Mink River wetland is not surrounded by a pristine landscape; yet, for the most part, the vegetation surrounding the wetland and river is similar to that before settlement. The township including the Mink River was surveyed in 1835. A map of the forest vegetation has been derived from Findley (1976 and personal comm) and from the General Land Office Survey Notes (Figure 6). Although most of the upland forest has been replaced by open fields and orchards, a northern wet forest, dominated by white cedar and tamarack with some black ash, still borders the river (Figure 7). An excellent northern mesic forest stand occupies the land just north of Rowley Bay.

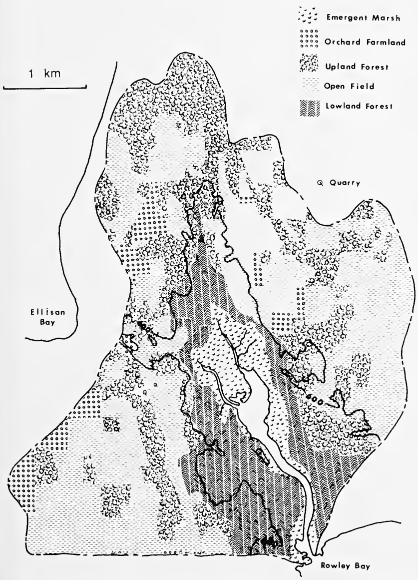

Fig. 7. A map of present land use in the Mink River watershed; note that the areas adjacent to Ellison Bay and Green Bay are not included here.

Present Vegetation

The emergent marsh along the Mink River is the most dynamic feature of the watershed vegetation. Lake level controls the succession of wetland communities along the Mink River. The marsh has contracted and expanded as Lake Michigan has risen and fallen. The plant communities present at a given time are the result of the opposing forces of community development and of disturbance. The extent of dominant communities in 1981 is illustrated in Figure 8.

During the 1980 and 1981 growing seasons, the emergent communities were

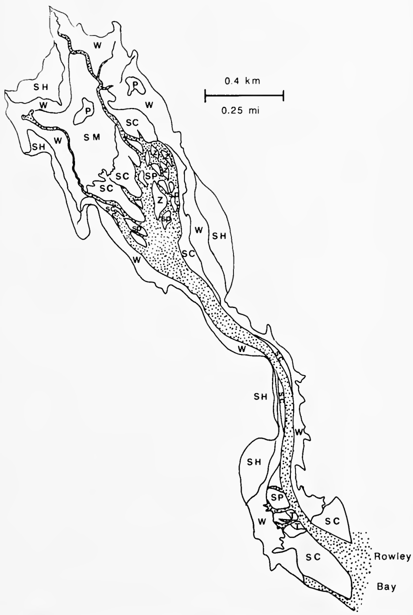

Fig. 8. A map of the vegetation of the Mink River estuary, as found in 1981-1982. Vegetation types are: SH, shrub carr; W, wet meadow; shallow marsh dominated by *Carex* (SM) and *Phragmites* (P); deep marsh dominated by *Scirpus* (SC), *Zizania* (Z), *Sparganium* (SP), and *Typha* (T).

TABLE 1. Plant species found in Mink River vegetation communities. Nomenclature follows Gleason and Cronquist (1963).

	Deep Marsh	*Shall. Marsh*	*Wet Meadow*	*Shrub Carr*	*Lowl. Forest*
Betula papyrifera Marsh.					X
Fraxinus nigra Marsh.					X
Abies balsamea Mill.					X
Tsuga canadensis Carr.					X
Populus deltoides Marsh.					X
Thuja occidentalis L.				X	X
Acer spicatum Lam.				X	X
Larix laricina K. Koch.				X	X
Alnus rugosa Spreng.				X	X
Cornus stolonifera Michx.			X	X	
Salix spp.			X	X	
Spiraea alba DuRoi.			X	X	
Calamagrostis canadensis Beauv.			X	X	
Iris virginica L.			X		
Eupatorium maculatum L.			X		
Campanula aparinoides Pursh.			X		
Gerardia purpurea L.			X		
Lobelia kalmii L.			X		
Chelone glabra L.			X		
Juncus effusus L.			X		
Acorus calamus L.			X		
Carex stricta Lam.			X	X	
C. hystericina Muhl.			X	X	
C. diandra Schrank.			X	X	
C. lacustris Willd.			X	X	
C. rostrata Stokes.			X	X	
C. aquatilis Wahl.		X	X		
C. prairea Dewey.		X	X		
Phragmites australis (Cav.) Steudel.		X	X		
Typha latifolia L.		X	X		
T. angustifolia L.	X	X			
Sagittaria latifolia Willd.	X	X	X		
Scirpus atrovirens Willd.			X		
S. validus Vahl.	X	X			
S. acutus Muhl.	X				
S. americanus Pers.	X				
Eleocharis smallii Britton.	X				
Sparganium eurycarpum Engelm.	X				
S. chlorocarpum Rydb.	X				
Equisetum fluviatile L.	X				
Zizania aquatica L.	X				
Potamogeton pectinatus L.	X				
P. richardsonii Rydb.	X				
P. praelongus Wulfen.	X				
P. gramineus L.	X				
Myriophyllum spicatum L.	X				
Polygonum coccineum Muhl.	X				
Elodea canadensis Michx.	X				
Nuphar advena Ait.	X				
Nymphaea odorata Ait.	X				
Chara spp.	X				

sampled, and observations were made of submergent species (species are listed in Table 1). Estimates of biomass were made using samples of above- and below-ground material harvested in each community every month during the two growing seasons. Peak biomass values from that period are presented in Table 2, and each community is described below.

Deep Marsh

The deep marsh complex occurs adjacent to channels of the Mink River. Several species form this community type, but seldom do more than two or three occur together. For example, *Sparganium eurycarpum* forms monotypic stands near the river mouth and in patches on mud flats in "Rogers Lake." Occasionally, a few individuals of *Sagittaria latifolia* are intermixed with *Sparganium*. *Zizania aquatica* is found in monotypic stands on mudflats. *Zizania* populations fluctuate widely from year to year; dense populations are found only during years when mudflats are exposed or near the water surface. For example, in 1982, the level of Lake Michigan was 6 inches lower than in 1981. Mud flats were exposed in Rogers Lake, and supported more numerous and dense *Zizania* populations than the previous year.

Scirpus validus occurs over a wide range of water level conditions. This species forms monotypic stands on shallow organic mudflats around Rogers Lake. With *Sagittaria latifolia,* it forms two-species stands along the Mink River channel. A tall form, probably a hybrid with *S. acutus* (Galen Smith, pers. comm), grows with *Eleocharis smallii* around the edge of Rowley Bay. *Scirpus americanus* also forms monotypic stands in deep water in the open bay, where the populations are exposed to wind and waves. *Typha angustifolia* also forms single species

Table 2. Peak biomass of emergent herbaceous communities of the Mink River estuary in 1981. Month of peak biomass occurrence is indicated.

Community Type	*Above Ground* *g/m² (month)*	*Below Ground* *g/m² (month)*	*Areal Extent* *km²*
Deep Marsh			
Scirpus validus Community			
in Rowleys Bay	595.4 (Aug)	1373.6 (Aug)	0.474
along Mink R. channel	204.1 (Aug)	268.6 (Sept)	0.052
shallow marsh edge	194.9 (Aug)	336.6 (Sept)	0.285
edge of Rogers Lake	410.1 (Aug)	493.6 (Sept)	0.050
Sparganium eurycarpum Community			
at river mouth	512.7 (Aug)	704.0 (Sept)	0.120
Rogers Lake islands	628.2 (Aug)	400.3 (Aug)	0.100
Zizania aquatica Community			
Rogers Lake islands	545.5 (Sept)	207.7 (Sept)	0.073
Typha angustifolia Community			
at river mouth	880.6 (Aug)	1626.4 (Sept)	0.041
Shallow Marsh			
Carex aquatilis/C. prairea Community			
between headw. creeks	327.1 (Aug)	806.0 (Sept)	0.496
Phragmites communis Community			
between headw. creeks	686.1 (Sept)	1867.6 (Sept)	0.060
Wet Meadow			
Calamagrostis canadensis/Carex stricta Community			
along river	779.7 (Sept)	6486.8 (Sept)	1.968

stands along the Mink River channels and in Rogers Lake.

Shallow Marsh

This type includes two species associations. An even mixture of *Carex aquatilis* and *C. prairea* forms extensive meadows that fringe the spring-fed channels upstream. These are the only two species in most of the area; along the channel-marsh interface, they mingle with *Typha latifolia, Phragmites australis, Scirpus validus, Calamagrostis canadensis* and *Carex stricta. Phragmites australis* is found to be dominant in extensive clones within the area of the *Carex aquatilis-prairea* community. This species forms a complete canopy with individuals of the two *Carex* species as a sparce understory. *P. australis* is common in disturbed wetland sites in Wisconsin, but in the Mink River shallow marsh there is little evidence of human disturbance. However, *Phragmites* may have invaded the wetland after a disturbance, such as a fire during a dry period of low lake level. The reason for its continued persistence is not known.

Wet Meadow

A wet meadow community dominated by *Carex stricta* and *Calamagrostis canadensis* borders the entire marsh. This community is the most diverse wetland type around the Mink River and includes several carices and other forbs (Table 1). Some of these, including *Calamagrostis, Campanula aparinoides,* and *Lobelia kalmii,* are modal in fen communities in Wisconsin (Curtis, 1959). Wet meadow borders swamp forest and shrub carr, and is often invaded by woody species (*Salix* spp. *Cornus stolonifera, Thuja occidentalis, Spiraea alba*). Dead woody stems are frequently found, evidence of past invasion thwarted by periods of high water.

Review of early aerial photographs suggests that this community may be resistant to long-term fluctuations in water level. The co-dominants, *Calamagrostis canadensis* and *Carex stricta,* occupy tall (up to 50 cm) hummocks formed by the latter, often surrounded by shallow standing water. These hummocks may provide a habitat that is not appreciably affected by changes in water level, or may permit development of propagules over a wide range of elevations above water. Substrate cores were taken in all wetland populations. Except in cores from the wet meadow, all of the present plant communities were underlain by remains of different species. Sedge and grass roots and rhizomes were found within and under the hummocks, suggesting that, while other communities were shifting with time and environmental conditions, the wet meadow has been persistant. Pieces of wood were occasionally found in cores, indicating temporary invasion by trees and shrubs.

Shrub Carr

The interface between the marsh and the surrounding upland is inhabited by a mixture of small trees, shrubs, and herbaceous wetland species, forming a shrub carr community that expands and contracts with the changing lake level. Species such as *Cornus stolonifera, Spiraea alba, Alnus rugosa* and seedlings of *Thuja occidentalis, Larix laricina, Acer spicatum,* and *Salix* spp. invade the wet meadow during drier periods. Dead stems indicate the return of high water. This appears to be a temporary community, as long as occasional periods of high water conditions continue to occur. With a drastic long-term lowering of water level, this community would probably develop into lowland forest.

Lowland Forest

A lowland swamp community surrounds most of the Mink River marsh. *Thuja occidentalis* is dominant, but there are significant numbers of *Betula lutea* and *B. papyrifera, Fraxinus nigra, Larix laricina, Populus deltoides, Acer spicatum,* and *Abies balsamea.* The importance of each varies greatly and is probably dependent on stand history and hydrology. This lowland forest has been disturbed by logging and by natural events. The latter are evidenced by much wind throw and root upheaval, resulting from flooding, storms, and ice activity. This forest community has largely protected the river and wetland from human disturbance by virtue of the wet organic soil and dense vegetation.

Wetland Community Biomass

During the 1981 growing season, biomass samples were collected monthly from the major emergent vegetation types. These are presented as peak above-ground and below-ground biomass estimates (Table 2). Shrub carr, swamp forest, and *Scirpus americanus* communities were not sampled. Submergent vegetation also was not sampled because, in general, individuals occur in small patches amid emergent plants, and because representative sites could not be identified. The areal extent of each community is a highly dynamic parameter that will vary from year to year as the communities expand and contract in response to lake level changes. The extent of each of these communities was estimated in 1981 (Table 2).

Peak biomass alone is not adequate to represent relative vegetation importance, however. *Zizania aquatica* is an example of an annual plant in which a cohort of seeds develops simultaneously, all flowering and setting seed at roughly the same time. Perennial species, on the other hand, develop rhizomatous ramets continuously during the growing season; examples of these are *Eleocharis palustris, Scirpus validus,* and *Sparganium eurycarpum;* some of these, such as *Sparganium* and *Typha angustifolia,* exhibit synchronous flowering and seed set as well. Stem death may occur throughout the growing season; this is evident within the *Scirpus* populations upstream from Rowley Bay. Often, peak above-ground and below-ground biomass did not occur during the same month. Those populations that peaked in September also had seeds maturing at that time. In other communities, stems and leaves were senescent by September. Most rhizomatous species develop storage material and over-wintering buds in the fall. Nonetheless, measurements of peak biomass permit comparison between communities and provide estimates of the maximum amount of production available to the system food web.

The wet-meadow community produced the largest peak biomass and had the greatest areal extent. This is intriguing in light of the apparent stability of this association. Much litter is present throughout the year, suggesting that production does not immediately enter the food web, and that this is a zone of accumulation. The shallow marsh community also seems to accumulate litter. The above-ground biomass of deep water communities is lost over winter, presumably broken up and removed by ice action, spring runoff and high water. Rafts of *Scirpus* stems are found along the beaches in spring; however, the amount and distribution of annual dead biomass through the river and bay is not known. The fate of production from other deep marsh species, whether by decomposition or outflow, is also unknown.

Discussion

The Mink River estuary is one of only a few Lake Michigan coastal wetlands that have not been significantly influenced by human activity. As such, it provides an opportunity to learn how plant and animal communities and individual species adapt and function in the coastal zone. The Mink River estuary, like other coastal wetlands, is subjected to various degrees of natural disturbance—principally changes in water level, but also massive ice movement and wave and wind activity. The low diversity of most plant communities in Rowley Bay and along the Mink River suggests that this site may be subject to more than average disturbance. The deep water communities experience the largest long-term changes in water level, as well as substantial wave action. Natural disturbance is sufficiently intense and frequent that there is not enough time for the development of diverse communities.

More protected communities, such as the wet meadow around the edge of the wetland, are more species-rich. The wet meadow community develops on and around *Carex stricta* hummocks; this topographic diversity, located higher in the watershed, permits the establishment of more species. Keddy and Reznicek (1985) suggested that the zonation of communities may be related to the position of maximum and minimum high water. They suggest that certain communities—wet meadow and shallow marsh—depend upon periodically exposed substrate for seed establishment. This appears to be so in the Mink River system; only those species that can survive by reproducing vegetatively persist in deep water. *Zizania aquatica* requires mudflat conditions in spring to germinate. Woody species on the shrub carr do not establish on hummocks, but in the low spots on the wet meadow. They are repeatedly killed by high water. Regeneration of such communities seems to be in phase with the cycle of low water conditions in Lake Michigan.

Little is known about the food web associated with Lake Michigan coastal wetlands. Harris et al. (1977) and Roznik (1978) have suggested that certain birds may respond to the dynamic structure of these emergent plant communities as water level changes from year to year. Furthermore, little is known about how the chemical gradient along the river may influence the distribution of aquatic plants or animals. Many intriguing questions can be raised concerning long-term fluctuations in biomass production by the various plant communities, as well as the fate of biomass and its contribution to the food web of the river and bay. Much can be learned about the adaptations of organisms in such a frequently disturbed coastal environment. Examples include the adaptations to long-term water level fluctuations by *Carex stricta* and *Calamagrostis canadensis*, by species of *Scirpus* (*S. americanum, S. acutus,* and *S. validus*), and by *Zizania aquatica.* While some coastal wetlands have been protected as natural reserves and are recognized as including unusual species associations or unique habitats, many biological and physical dynamics are still waiting to be explored.

Acknowledgements

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PLEISTOCENE CARIBOU IN CENTRAL WISCONSIN

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In the summer of 1985, Jack and Mona Zelienka found an antler while excavating their peat bog 6 miles southeast of Coloma, on County JJ in the township of Richford, Waushara County, Wisconsin. The antler was stained and heavy with mineral replacement, obviously of great age, broken at all distal aspects (during excavation), and was shed from a Late Pleistocene caribou (*Rangifer tarandus*). The bog, which had been previously excavated 10 to 12 feet in some places to create a pond, was deepened to nearly 30 feet. Subsequently the antler was discovered in the excavated sediments of marl and peat; its depth in the peat was estimated at between 12 and 25 feet. The bog is sited near the proposed Ice Age Trail along the Wisconsin terminal moraine in Cary drift. This is the first record of the caribou from central Wisconsin, and one of but a few for the state.

The antler (all in one piece) consists of a brow tine (or "shovel") with tip broken away (length 153 mm); a main beam approx-

Fig. 1. Antler of caribou excavated from peat in Richford Township, Waushara County, Wisconsin.

imately 625 mm measured to the terminal palmate expansion, broken off and hollow; from the burr about 150 mm to the base of the first palmate tine; and along the beam 260 mm beyond to the next and opposite tine (entirely broken away). The length from tip of brow tine to the broken expansion is approximately 700 mm. The first palmate tine on the main beam measured 350 mm from the beam to the deepest notch of the palm, which was 205 mm across. Its greatest length was 392 mm. The diameter of the ovate base, shed from the pedicel, is about 42 to 47.5 mm in diameter, and of the burr approximately 61.5 mm (see Fig. 1).

Never common in Wisconsin and Upper Michigan in historic times, caribou wandered into these areas from muskeg habitats in nearby Minnesota and Ontario. A. W. Schorger (1942) reviewed the records and reports of caribou, listing several from the Upper Peninsula of Michigan and questionable ones for the Brule area in northwest Wisconsin, probably escaped animals from the Pierce estate. Among prehistoric bones found in Polk County, also northwest Wisconsin, a few were reported as caribou (Eddy and Jenks, 1935).

The caribou apparently wandered into lower Michigan after the Wisconsin glacier receded. Specimens were dated at 11,200 and 5,870 ± 200 years BP. Baker (1983) suggests that historical records represent the woodland caribou, whereas the prehistoric caribou were of a larger Arctic form (but the woodland caribou is a large form). Subspecific characters are hardly obvious in broken and fragmentary remains of antlers. Even the sex is impossible to know. Banfield (1974) and other Canadian workers considered all the large woodland caribou to belong to one subspecies, *R. t. caribou.* Apparently all the caribou in Wisconsin belonged to this species and descended from the same stock.

The antler herein described is slightly smaller but very similar in form to that figured by West (1978) from southeast Wisconsin. The nearest of his records is approximately 150 km southeastward, in Sheboygan County. The other is from Wauwatosa, near Milwaukee.

West (1978) assigned his specimens to Late Pleistocene age, one antler dated by its sediments to about 12,500 years BP. In summary, all known prehistoric caribou from Wisconsin are scattered along the front of the Wisconsinan moraines in Polk, Waushara and Sheboygan counties, and near Milwaukee. I acknowledge with thanks the cooperation of both of the Zelienkas.

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TECHNOLOGY, INSTITUTIONS, GLOBAL ECONOMY AND WORLD PEACE

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It seems quite natural for creative human beings to invent or modify techniques for satisfying their changing needs and wants. In this process and over time, the concept of what constitutes a natural resource changes with changing human aims, objectives and ambitions. What constitutes a resource in human terms is indeed a function of knowledge and technique. Only a little more than a century ago petroleum near the surface was considered a nuisance; today it is referred to as black gold. The moon was a romantic symbol and outer space a void throughout most of history; today both are becoming highly prized resources. The changing view of resources brought about by new knowledge, new techniques and new wants often leads to conflict. New or modified human institutions are required to manage these conflicts and to keep them from destroying the community.

Changing techniques and scientifically advanced technologies, like new resources, often require a redefinition of the political unit that makes public policy. In the more or less self-sufficient Wisconsin farming communities of 100 years ago, where the major source of power and transport was the horse, local communities could set the rules. But with the coming of the automobile, a hodgepodge of local rules and regulations proved chaotic. The building of roads, the registration and licensing of both vehicles and drivers, the handling and sale of gasoline, the responsible and safe use of these powerful "horse-less carriages," etc., required a new set of institutions and a larger political unit to make public rules. The State of Wisconsin had to get involved in these policies. Neighboring states had to coordinate their policies on a number of issues and still other policies had to be set at the national (federal) level. The airplane created still more complex problems, and commercial air travel could not function today without at least minimal international rules and procedures—for example a common language for international air traffic controllers and common safety and security procedures.

As I look at our national experience over the past 50 years or so, within my own lifetime, it seems that our policy response to problems created by ever changing technologies and new resources has moved from local to state to federal levels. I think this shift has been mostly the result of three factors: (1) Technology made the local community an inappropriate political unit for policy, thus the regulatory powers of government have shifted from the states to the federal level. One good example is in the regulation and control of the increasing number of complex chemical compounds used in many production processes. (2) Our large internal common market made policy at the state level an ineffective instrument for various forms of market intervention—e.g. farm policy, product safety, labor legislation, setting and monitoring standards, etc. These too are related to technological innovation resulting in an ever increasing labor mobility and a changing market structure of the economy. (3) Institutions at the state and local level have at times failed to protect equally the individual rights guaranteed by the federal constitution and so various questions of social, economic, and civil rights were appealed at the federal level.

The role of the federal government and our interpretation of appropriate action under the constitution also gets re-defined, especially in times of crisis. Our view of the appropriate role of the federal government in economic planning and intervention in the economy of the 1930s, or its role in defining and protecting the civil rights of all citizens in the 1950s and 1960s, are good examples of such re-definition.

I wish to emphasize that it is the level at which policy is *formulated* that has shifted to the more comprehensive political unit. Managing the consequences of powerful technology and avoiding chaos through relative uniformity of rules must be addressed by policy at this higher level. Implementation, of course, may remain at the local level. And I certainly do not minimize the very important, creative and experimental nature of state and local governments in tackling problems and setting patterns for action later taken and made applicable at the federal level. This has been a common pattern throughout our history. One of the areas in which we see this local experimentation operating today is in the variety of community land trusts, public development corporations and collective property rights institutions. I also admit to the likelihood of decentralization in the private economy and even new prospects of cottage industry based on the computer as suggested by Alan Toeffler in *The Third Wave*. Yet while this may be one impact of computers, their increasing power and complexity and potential for misuse is also bringing more federal concern and control.

This interacting process outlined earlier—new wants, new knowledge, new techniques, new resources, new conflicts, new policies, new institutions, and yet additional new wants, etc.—is not new. What has changed and *what is relatively new* is the power and scope of our modern technologies. The consequences of many modern technologies cannot be confined to local communities, and in many cases cannot even be confined to the political units called nations. Ours is a world, says Harlan Cleveland,

> "where science, which has always been transitional, keeps inventing inherently global technologies—for weather observations, military reconnaissance, telecommunications, data processing, resource sensing, and orbital industry. As a result . . . we find ourselves moving beyond concepts of national ownership, sovereignty and citizenship to ideas such as the global commons, the international monitoring of global risks, and 'the common heritage of mankind'" (Cleveland, 1985).

We live now in a world of increasing economic interdependence among nations whose institutions remain geared to addressing problems within their own national boundaries. But the scope and reach of global technology has consequences beyond the control of these national institutions. Despite the size of its economy and its sophisticated science, the United States is tied into this web of interdependence just as other nations are. We can no longer withdraw from the world and return to the isolationist ideology of a century ago, nor can we dominate the world, a role more or less dictated to us by circumstances for 20 years after World War II.

The US now depends on foreign sources for more than half of its supply of 15 minerals crucial for our industrial and post-industrial technologies. For 8 of these minerals, import dependence runs between 80 and 100 percent. Oil production within the US is not likely to see a major spurt and we will probably become increasingly dependent on oil imports. Our agriculture and parts of our manufacturing industry depend heavily on foreign markets.

One important change in the world economy has been the dramatic increase in world wide trade. The dependence of the US economy on international trade tripled in the period 1965-1979. A corollary of this increased trade is an economy less amenable to direction by domestic economic policies. These last twenty years, concludes G. Edward Schuh,

> "have been a period in which the economic integration of the international economy has far outdistanced its political integration. In fact, we have witnessed a successive breakdown and growing irrelevance of international institutions at the very time that our respective economies have become increasingly integrated. Domestic economic policies have less and less relevance in today's world, and do little more than create suspicion and lack of confidence in national governments since their policies do less and less what they say they will" (Schuh, 1985).

"No nation," concludes Harlan Cleveland, "controls even that central symbol of national independence, the value of its money; inflation and recession are both transnational."

Perhaps the closest we have come to a really transnational institution with power to enforce its decisions is the increasingly complex multi-national corporation. Although they have been much criticized for some of their international practices, often appropriately, it is almost impossible to conceive of the world economy functioning without them. One-fifth of the world's gross product is created by these multi-nationals—more of them based in the US than anywhere else. In many commodities, world trade is dominated by the multi-nationals, and a large part of registered international trade is indeed the internal transactions of these international companies. With cheap and rapid transportation and instant communication, these large multi-national corporations have the capacity quickly to shift capital, technology and management all over the world. Is it any wonder that national policies do less and less of what they say they will?

Strong *economic* interdependencies, however, are not the only global ties among nations. Another major consequence of modern technologies is their environmental impact. More and more species are threatened with extinction. The burning of greater amounts of fossil fuels and widespread deforestation in various parts of the world raises the CO_2 content of the atmosphere. Acid rain and dying forests are not confined to the areas where the sulfur compounds enter the atmosphere.

Of course, the most powerful and potentially destructive technologies of all are nuclear weapons. This has led many to reevaluate the meaning of "national security"—concluding that such security is not likely to be found in more weaponry of increasingly devastating power. There is, says Thomas Wilson,

> "an unavoidable nexus between the security of a nation and the state of the planet; there is a connecting link between the peace of nations and the integrity of natural systems; there is a critical relationship between international order and ecological balance. Indeed, the threat to the security of nations today is much more easily comprehended from an ecological than from a military perspective. This point is made with great force by the . . . 'Nuclear Winter Study'" (Wilson, 1985).

Modern science and technology have brought new possibilities for global (and indeed extra-global) actions and impacts. The reach and power of some of these technologies have consequences that cannot be contained in national decision-making systems. The human drive to "control nature for human purposes" must itself be controlled to avoid the potential widespread destruction of natural systems, without which human life would be impossible. The international institutions thus far created are not yet capable of dealing constructively with the global problems that modern science and technology have borne.

My comments should not be interpreted as being in any way anti-science or anti-technology. The earth's 4-5 billion people and the many yet to be added before world population levels off (even with the best of efforts and the use of new technologies) cannot be fed without continued developments in science and technology. Nor can critical soils and fragile environments be protected and preserved without new scientific knowledge and its well-designed technological application. These must be selective developments, to be sure. All that is new and all that is possible is not necessarily desirable. We must by all means give as much public policy and institutional attention to alleviating the negative socio-economic and environmental consequences of technological developments as we do to the fostering and the diffusion of new technologies. Science and technology have negative consequences as well as positive ones. But those negative consequences are likely to call for more research, new knowledge and additional developments in technology.

In view of these urgent global problems, national policies often seem petty and contradictory. Said Saudi Prince Sultan Saud as he looked out the window of the space shuttle Discovery, "Looking at it from here, the troubles all over the world and not just the Middle East look very strange as you see the boundaries and borderlines disappearing. I think lots of people who are involved in causing most of these problems ought to come up here and take a look."

Must we wait for world government before any progress can be made in controlling these potentially destructive trends? We should recognize that some progress has been made on a variety of issues. International need not always be global and involve all nation states. In several areas nations in a particular region are working together on common problems. In other regions, of course, adjoining nations are at war. We are not very far along the path of creating appropriate institutions and enforcement powers to control some of the threatening consequences of the new technologies. In a view that's probably over optimistic, Thomas Wilson (1985) concludes:

> "If national security is dependent upon world security . . . if there is no other way to save our own outstretched necks—then the imperative drive of national interest in national security impels governments not toward divisive and hostile behavior but toward cooperative and collaborative behavior in world affairs, whether they like each other or not."

There is an urgent need for new institutional forms to deal with the complex issues threatening the global economy and environment. Fashioning such transnational institutions would be more easily accomplished in a world at peace rather than a world of suspicious and warring nations. Individual nations, especially the biggest and the most powerful, must seek cooperation and accommodation rather than threats and confrontation, dialogue and debate rather than accusations and denunciations.

As educators, we must recognize that many issues can no longer be kept in separate compartments for domestic and international solution. Most major domestic policies of the United States have significant effects on almost every other nation. What the United States is able to do, or wants to do, also depends increasingly on the acts and policies of other countries. That is what interdependence means. Educators at all levels must be aware of the fact that in a democratic system where people are the ultimate policy makers, individual citizens must be taught to understand these complexities. And elected officials must be able to comprehend these issues so they can help educate the public and provide the informed judgments required for sound policies.

In analyzing the need for institutional change to resolve domestic conflicts and attempt to make private, individual action consistent with the larger public purpose, the late John R. Commons, Wisconsin's great institutional economist, suggested that it is quite reasonable to expect that individual action is intended to serve individual goals and purposes. The real question, however, is whether individual action also furthers, or at least does not conflict with, the larger public purposes, or whether it serves *only* private purposes (Commons, 1924). We might paraphrase Commons and suggest that individual nations today must see their own policies in a similar light: it is not a question of whether their policies should serve their own national purposes, that must be taken for granted. But the real question is whether national policies also advance, or at least do not conflict with, the broader international public purposes. In our increasingly interdependent world, self interest must be re-evaluated constantly. Following a course of narrow self interest, whether at the individual level or that of the nation state can be self defeating and destructive.

We must learn to extend our sense of community to peoples in far away places with customs and beliefs quite different from our own. Extending and identifying our self-interest within ever-widening contexts is a basic ingredient of human history. For most people the nation state was the latest of these extensions. But these urgent global issues now require that we extend our empathy to other people around the world. Achieving this is the fundamental role of new institutions. This, of course, requires a positive effort on all our parts to understand other peoples and their cultures, their languages, their history and their aspirations.

We are born into a world of going concerns and established institutions. We essentially inherit a system and take its governing institutions pretty much for granted. Most of us do not get involved in creating new institutions. At best we help to reshape the ones we inherited, and then usually only marginally. Creating new transnational institutions to deal with truly global issues, whose rules and procedures provide mutual benefits and mutual restraints for the weak as well as for the powerful will be an immense task. We must not underestimate the difficulties involved. But neither can we withdraw and fail to address these issues—in our schools, at our universities, in political debates.

It does, perhaps, call for a new type of citizenship, where the responsibilities of citizenship are defined in a broader context. We must be ever conscious not only of the lives and the needs of other humans on this space ship earth—this global village. We must also be increasingly sensitive to the protection of the natural systems which sustain us. In closing, I should like to quote from a 1922 book by L. P. Jacks entitled *Constructive Citizenship.*

> We human beings are apt to think our race the only object in creation that really matters. We have developed a kind of class-consciousness in presence of the universe. The human race is all-important in its own eyes: nature is there to be ruled by us; her forces are meant to turn our wheels; her materials to be exploited for our enrichment; her laws to provide for our comfort; and the very stars in their courses must be yoked to our wagons. We have still to learn that the human race is tolerated in the universe only on strict conditions of good behavior. If we neglect our citizenship there, or think that we can play fast and loose with the laws that are written there, laws that were not voted into existence by us, those other citizenships will come to grief. This human class-consciousness in presence of the rest of the universe is not a good thing. It is a dangerous thing. Unless we bear that in mind, our study of the rights and duties of the citizen is not worthwhile (Jacks, 1922).

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"THE MAN WHO LIVED AMONG THE CANNIBALS": MELVILLE IN MILWAUKEE

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Early in 1886, after years of literary silence, Herman Melville began writing his last book, *Billy Budd.* He died five years later, virtually unnoticed, because many people believed that he had died years before. In fact, in twenty years of employment as customs' Inspector for the Port of New York Melville continued to write but published only a small volume of Civil War poems for public sale. He also wrote *Clarel* and another volume of poetry, both printed in limited editions for his family and friends. Therefore, the final phase of Melville's public literary career—and his last work in prose before *Billy Budd*—was a brief attempt at lecturing, during which he once toured the Midwest and spoke in Milwaukee.

Melville met with decidedly-mixed success over these years, 1857-60, and it became clear to him that he would not make much money, nor would he revive his popularity as the author of adventure and travel narratives. The lecture tours were really his last efforts to maintain a career as a popular writer, and their ultimate failure probably accounted for his decision not to make a prose romance out of his last adventure, his trip to the Holy Land in 1856-57, but the philosophical poem *Clarel,* written for intimate acquaintances. His first lecture was "Statues in Rome," adapted from this trip; his last was called "Traveling."

Ironically, his nearest success on stage went back to the beginning of his career. The lecture he delivered in Milwaukee and elsewhere his second year on speaking tour was "The South Seas," actually fitting the reputation he worked so hard to overcome as "the man who lived among the cannibals," as he summarized his reputation in a letter to Nathaniel Hawthorne.[1] It became certain, finally, that he could not appeal to audiences as an entertainer, like the reigning stage star Bayard Taylor and the later star, Twain, nor could he be accepted as a philosopher or social commentator, like the reigning sage of New England Ralph Waldo Emerson.

Melville spoke in Milwaukee on February 25, 1859. By the time he appeared there, a late stop during the second lecture tour, he was working much harder to please local crowds than most critics have assumed.[2] His subject, content, and delivery were calculated for stage success. However, the Milwaukee performance was fairly typical in its dubious outcome. In books, Melville could be risque, impudent, even raucous. However, this character he found only through literary personae; Melville in person was urbane, often subdued, even shy and uncomfortable among strangers. He lacked Twain's talent for embodying his literary characters. Melville in person was usually a New England gentleman who remembered his genteel roots. (With the possible exceptions of James Fenimore Cooper, James Russell Lowell, and Emerson, Melville had more claim to New England gentry than any of the prominent nineteenth-century writers.)[3]

Melville was thirty-seven when he decided to try lecturing, thirty-nine by the time he appeared in Milwaukee. He had been a writer for thirteen years and a farmer, too, for half that time; but now, with a chronic back problem that would plague him the rest of his life, he was forced to rely almost entirely on his father-in-law to support his family. Normally active and independent, Melville was irritated by the prospect of a sedentary life and family charity. He had already realized what many other writers more salable than he had found: few people could earn a living as an author, but several supported themselves writing and giving live appearances, by traveling the lyceum circuit. Melville was now unusually pressed for money. He was overdrawn on his accounts with publishers. One publisher of two recent books had gone out of business and was selling its plates, and another had lost its stock of some earlier books in a warehouse fire. Melville had nothing new ready for sale, having just returned from his trip to the Holy Land. A series of lectures seemed a practical venture for turning his recent excursion into something immediately profitable. So Melville wrote "Statues in Rome," an analysis of the philosophy of art, with an added dose of gossip and personal anecdotes. He knew the subject would attract little interest in itself.[4]

This first lecture, delivered through the 1857-58 lecture season (the winter months), generally received poor reviews. It was not a shrewd choice of topic for one whose forte was tale-telling rather than descriptive or critical analysis; moreover, reviewers generally agreed that Melville's delivery was rather dry. He had hoped for publicity to generate invitations and was thus disappointed. In addition, the reviewers tended to focus on characterizing the man who lived with the cannibals, rather than the author of a piece of statuary. Audiences preferred a glimpse of an entertaining personality, rather than a systematic analysis of works of art which they could not see before them. Nonetheless, he was sufficiently encouraged, and paid, to plan a second season in a more business-like manner. He began a correspondence to arrange a professional circuit from New England, into the Southern states, and through the Midwest, rather than waiting for invitations.[5]

An old family friend, William E. Cramer, editor and owner of the *Milwaukee Daily Wisconsin,* undertook the local publicity and might even have suggested Melville to the Young Men's Association, which sponsored the Milwaukee appearance. Melville spoke in Albany Hall, appropriately named to suggest that the city's cultural tastes were as refined as those of an eastern city, and Cramer appealed to civic pride, pointing out in advance notices that a well-attended lecture "always gives a stranger a good impression of the intellectual culture of the city."[6]

Melville had a promising field before him in Milwaukee in 1859; the city was growing and its affluent citizens eager to show their interest in things cultural. The Young Men's Association was composed, like many similarly-named groups in the Midwest and across Wisconsin, of business and professional men who were accumulating a library, presenting lectures and debates, and offering educational courses from a variety of cultural topics. A Young Men's Association or Young Men's Library Association existed in Beloit, Columbus, Fond du Lac, Janesville, Kenosha, LaCrosse, Madison, Oshkosh, Portage, Racine, Sheboygan, Watertown, Waukesha, and Waupun. They shared the name and corresponded on arranging programs, although they had no state-wide organization.[7]

In the 1850s, lyceums grew faster in the Midwest than any other part of the country and continued their popularity into the Civil War years. Chicago, Sheboygan, and Milwaukee were among the best stops for a speaker; the cities usually drew large crowds and offered good money—$50 a night was standard in eastern cities but only a few such stops existed in the West. Bayard Taylor once wrote from Milwaukee, "The people are infatuated. If I lecture next winter, I can spend three months in the West and have engagements for every night." This was Taylor's impression in 1854, when Milwaukee also heard such speakers as Emerson, Horace Mann, and Horace Greeley.[8]

Nonetheless, the midwestern audience was a somewhat difficult one for New Englanders. Newspaper reviewers were antagonistic toward any Easterner who showed the slightest trace of snobbery or disrespect for the culture of the West; in addition, the character of midwestern audiences and their expectations sharply differed from those in New England. The Young Men's Associations attracted people with social expectations and pretensions, but these lyceum organizations in the West belonged to a second phase of the movement and lacked its original New England roots in the drive for popular literacy and free public education. By the standards of the time, Wisconsin had already accomplished such improvements in its first decade of statehood. Consequently, audiences in this state and others in the Midwest demanded as much entertainment as edification and were generally unreceptive to speakers who appeared as though they wanted to "school" the audience.[9]

For instance, Cramer's paper pointed out that Melville's lecture was "entertaining" and "*also* instructive" (emphasis added), suggesting the educational material was secondary. Cramer wrote that Melville "lay open a field of *adventure* and *wanderings* to which one rarely has his attention called" (emphasis added). Melville found out that reviewers were quick to bristle at the suspicion that they were being patronized or treated like uneducated backwoodsmen. Milwaukee's literacy was accomplished in part by German immigration, half the city by 1860. The German population in particular regarded itself as better educated and cultivated than other nationalities, including the native Americans, and very much resented being considered a pioneer settlement.[10]

When Melville first published south-sea adventures like *Typee* and *Omoo,* he had been accused of romantic exaggeration of the exotic island life. His new lecture on "The South Seas," however, now brought occasional complaints among midwestern reviewers that he was rehearsing well known material which any library could yield. For once, Melville found himself accused of a want of originality and a failure to be sufficiently exotic and entertaining.[11] The *Milwaukee Daily Free Democrat,* for instance, commented, "On the whole, we think there are few who knew much more about the South Seas, after he concluded, than before he began." Melville had said that this lecture was not to be a personal narrative—"a great mistake," said the paper, "for had he stated some of the scenes which he had passed through himself, and thereby invested his lecture with some life, instead of telling us what the primary geographies told us in our schooldays, he would have created a better impression in Milwaukee."

The starting time for Melville's lecture was moved up a half-hour so that Albany Hall could offer a held-over performance of Father Kemp's Old Folks Concert Troupe, a costumed choir and orchestra with a variety of sacred and patriotic music. The choir alone numbered thirty-seven people; the group was billed as "The Largest Concert Troupe in the World." Melville was in competition with a musical extravaganza, and although the auditorium was reserved for him, he was obliged to defer to the more popular show. In fact, the newspaper advertisements for performances at Albany Hall and elsewhere indicate a demand for drama and musical entertainment. Other selections in the winter season included a "Grand Masquerade Ball" and "St. David's Vocal and Instrumental Concert." Melville's competition on February 25th at Johnson's Atheneum was selections from *The Merchant of Venice* and *Rob Roy.* The Atheneum was also booked for *Uncle Tom's Cabin,* partly a musical on stage, and *Ten Nights in a Barroom,* starring the popular cracker-barrel comedian "Yankee" Locke. Such variety acts of the lyceum stage have been called "prevaudeville."[12]

The advance publicity for Melville's lecture billed him as the author of *Typee,* his first book of south-sea adventure—not as the author of any metaphysical allegories, like *Mardi* and *Moby-Dick,* that were not selling now. Cramer had specifically reminded people that Melville had lived with cannibals and experienced episodes beyond the wonders of imagination. He did have exactly the kind of material that might keep an audience spell bound. Bayard Taylor was due in town for the Young Men's Association the next week, and his stage personality suggests what the audience preferred. Taylor, popular as a world traveler, wore costumes of places he described; his best known outfit was a pseudo-arab costume complete with scimitar. He avoided being a moral observer and spiced up his lectures with exotic-sounding poetry. He avoided using a script and the appearance of delivering a packaged performance. The *Daily Wisconsin* called his manner "enthusiastic" and "eloquent," noting his handsomeness made him popular particularly with the ladies. He spoke in Milwaukee on "Life at the North," travelogues being among the most popular stage programs. Taylor had accompanied Commodore Matthew Perry in the Pacific and had also some claim to being an expert on far-western islands. Taylor was willing to make money as a specimen from unknown parts of the world, an entertainer with adventure stories.[13] However, Melville, as everyone knew, had lived with cannibals and had experiences as wild as anything that Taylor might describe.

Nevertheless, Melville could not compete as a comparable entertainer, although he did make certain efforts to please his audience. He announced that this lecture was not to be an intellectual argument, but a collection of facts and impressions without a theme. Even his choice of material was a concession to popular taste. However, Melville's Pacific travels were fifteen years old and his memory less vivid than Taylor's. Melville had outgrown his former character. So he did not put all his material into the form of a personal narrative and actually opened with a summary of literary references on the South Seas and geographical information before recounting any of the "exceptional phenomena" that his audience had come for—indeed, was led to believe they would get, according to the advance publicity. In fact, there was little on cannibalism and no lewdness. Melville did attempt to appeal to the audience taste for the exotic and sensational with description of the bizarre "devil-fish," the art of tattooing, and a sly reference to the "awful ceremony" of the taboo, a subject he said that he could not reveal in such a proper atmosphere as this, although it contained strangeness transcending the wildest romances of Mrs. Radcliffe. He spoke about Free Lovers, Mormons, and various utopian societies seeking asylums, all objects of public curiosity at the time.[14] He recounted an anecdote of meeting a Professor of Moral Philosophy who had abandoned civilized life for the sylvan retreat of the islands and three wives, the kind of sailor's yarn that the reviewers could question (in good nature) and appreciate for its romantic sentiments; overstepping the bounds of the probable and decent might be dubious history and morality, but good theater. He even worked in a reference to the Newall House, a stylish Milwaukee hotel, to contrast primitive culture to civilized society. Imagine, he said, a bare-limbed savage with awful tattoos appearing at such a proper place; this image might appeal to civic pride, and, at the same time, the touch of titillation made good theater.

On the whole, however, Melville was "packaged" more obviously than an audience would desire. For instance, one attempt at describing sea colors, which reviewers noted, has a consciously rhetorical and literary style. Here is Melville's text, in an exaggerated gothic style with allusions to the Bible and *Paradise Lost:*

> I have been in a whaleboat at midnight when, having lost the ship, we would keep steering through the lonely night for her, while the sea that weltered by us would present the pallid look of the face of a corpse, and lit by its spectral gleam we men in the boats showed to each

> other like so many weather-beaten ghosts. Then to mark Leviathan come wallowing along, dashing the pale sea into sparkling cascades of fire, showering it all over till the monster would look like Milton's Satan, riding the flame billows of the infernal world. We [theater audience] might fill night after night with that fertile theme . . . and tell of the adventurous sailors. (165-66)[15]

However, Melville dropped the scene for that night and had nothing marvelous to develop from such supernatural portent. He made no real effort at suspense and delivered the description without any spontaneity or sensationalism in which the audience might participate. The *Daily Free Democrat* thus complained that Melville offered few illustrations beyond general comments, cut short the personal anecdotes, and then gave "word-painting" rather than anecdotes with "any inherent or thrilling interest."

Melville was most emphatically himself in an ironic passage criticizing missionary work as personal gain, jingoism and colonialism, and Emersonian optimism:

> [T]he result of civilization, at the Sandwich Islands and elsewhere, is found productive to the civilizers, destructive to the civilizees. It is said to be compensation—a very philosophical word; but it appears to be very much on the principle of the old game, "You lose, I win": good philosophy for the winner. (179)

Although he announced no theme to his lecture, Melville had an explicit message: leave the islands alone. He told his audience that Americans should have no pretensions of civilizing other people until they civilized themselves. He meant no particular criticism of his audience here, although such a remark was ill-placed in Milwaukee, especially before people who subscribed to a lecture program chosen to represent a highly-refined, established culture, and who were also drawn to hear Melville by Cramer's advice that they show interest in intellectual offerings. As in the reference to the Newall House, Milwaukeeans wanted to be complimented for their civilization. They may indeed have come principally for entertainment; however, they were not going to applaud heartily for someone who would lift the veil only slightly upon the voluptuary life of the South Seas they imagined, and who then told them that they had no right to gawk upon the rest from any superior perspective. Bayard Taylor encouraged audiences to imagine themselves in foreign lands; Melville told them to stay home and civilize themselves.

In the words of Cramer's review in the *Daily Wisconsin,* adventurers had "no right" to interfere with existing cultures. The United States should leave Hawaii alone and thus keep it from "the demoralizing associations of modern civilization." Even Cramer, who was determined to be sympathetic to Melville in his paper, did not comment on the sentiments his friend expressed. He would not criticize him, but Cramer could hardly tell the civilized people of Milwaukee that they were no better than naked savages and that the tattooed Polynesian would be as amused by the elegant functions in the Newall House as its patrons would be by him. Cramer did little more than summarize the lecture after some opening impressions of Melville as a speaker. He wrote favorably of Melville and his delivery, endorsing the lecture as a whole, but avoiding specific support for the themes.

The *Daily Free Democrat* had no restraint; the audience would have preferred, it said, "personal reminiscences . . . to such bombast." So, "The lecture was attentively listened to," noted the reporter, "but the appreciation of it, we think, was testified by the limited applause at the close. The Association, we think, received more profit from the lecture than the audience." The snide remark that the audience had not gotten its money's worth was about the worst judgment a reviewer could pronounce. People were not going to quibble too much about a speaker's sentiments, so long as the speaker was entertaining. For this one observer, at least, Melville had not passed the crucial test. The *Daily Free Democrat* said Melville had a "large audience . . . perhaps the most of whom were disappointed in the lecturer." He gave "a literary effort below mediocrity, unless he intended it as a reading. In fact, it seemed as though he had one of his romances before him, and had selected the most uninteresting passages to read for our edification." The audience listened "attentively," according to this report; however, newspapers invariably complimented local audiences so, sometimes the greater to criticize an uninteresting speaker. "[S]o general were his remarks that they failed to create much interest in the minds of hearers," the paper said.

The *Daily Sentinel* agreed that Melville had "an unusually large audience" to hear him talk about the beauties of the tropics "in his own inimitable way." The *Sentinel* offered little actual review and principally summarized the lecture, as the *Daily Wisconsin* had done. Only the hostile *Daily Free Democrat* undertook a critique rather than a summary. Although the *Sentinel* would appear to have approved of Melville by its comment on his "inimitable" style, the compliment is hardly hearty and even has a certain irony. Familiarity with the idiom of newspaper reviewing in the nineteenth century suggests that the term was something of a cliche; it was often used in advance publicity in place of anything more precise, and in a review, it may mean only that the reviewer had not really observed anything remarkable. "As a lecturer," the reporter noted, "Mr. Melville sustains the idea we have formed of him in 'Typeer' [sic], a soft voluptuous ease is the predominant characteristic. . . . [T]he same drowsy enchantment that makes his writings so fascinating radiates from the speaker." The *Sentinel*'s reviewer might have been a subtle reader of Melville, if indeed he had read Melville, for few critics would have called *Typee* "drowsy enchantment." The book actually had been accused of lewdness, Munchausenism, and trumped-up criticism of colonial missionaries. Moreover, Melville read his new material from a script—only the *Daily Free Democrat* was unhappy for this—but, even though the *Sentinel* did not register any criticism of its own, its report of Melville's subdued manner was not generally an endorsement of stage skill. Audiences usually preferred a more animated speaker. In a sense, the *Sentinel* had called Melville "bookish," a term the *Daily Free Democrat* used as sharp criticism.

Cramer's review in his own paper was the only solidly-complimentary one that Melville received. The *Daily Wisconsin,* in fact, said a "very large and appreciative audience" heard Melville, although it did not judge the applause, as the *Daily Free Democrat* had done. The *Daily Wisconsin* denied that Melville read a "stilted lecture" nor indulged in "rhetorical flights," but instead spoke in "delicious literary languor . . . graceful and musical." Melville was not one for stage theatrics, but instead spoke "as one would like to sit down to a club room, and with the blue smoke of a meerschaum gracefully curling and floating away . . . dream for hours, even till the night wore away." Cramer's simile was appropriate; in fact, Melville was generally best in intimate surroundings.

Albany Hall seated about 800 people. The actual attendance can only be estimated—all papers called it "large"—but despite the *Daily Free Democrat*'s insinuation about the Young Men's Association profiting at the audience's expense, the receipts do not suggest a tremendously successful booking or a capacity crowd. The Association actually lost money on the particular performance. The ledger records $50.45 received at the door, $50 for Melville's fee, and another $29.50 for expenses. The door receipts do not include subscribers to the season lecture program, but there is no estimate of exactly how many members attended. Ticket prices were 25¢, the standard charge for stage performances (Father Kemp's Troupe charged the same). At any rate, the "large" crowd did not draw enough from the public to meet expenses for the performance. A "large" audience was another standard comment in reviews and might often mean no more than an average crowd. For instance, the *Sentinel* specifically said that Father Kemp's concerts were "fully attended. . . . The Hall will be hardly large enough to hold all who wish to hear them," the paper predicted. The *Daily Wisconsin* complained that ladies were forced to stand.[16]

So, it is doubtful if Melville had anywhere near a full house. The Young Men's Association did not renew its invitation to Melville when he expressed interest in performing a third season. Melville did get bookings the next year in the East but received almost no response from places on his midwestern tour. Melville was not cut out to offer the kind of entertainment which inspired enthusiastic reviewers and return crowds, who had plenty of top-name talent to choose from. By estimates, Melville was only the sixth most popular of ten speakers on the Association's 1858-59 program in Milwaukee.[17]

Cramer's review in the *Daily Wisconsin* was favorable; the *Sentinel*'s was essentially noncommittal; the *Daily Free Democrat*'s was hostile. The *Daily Wisconsin* and *Sentinel* put Melville on page one; the *Daily Free Democrat* put him back on page three. All told, Melville did comparatively well in Milwaukee. He also appeared in Chicago, Rockford, and Quincy, Illinois, but got few good reviews, most observers agreeing that he had no distinctive stage personality, seemed too rehearsed, and spoke too softly. The eastern reviewers had been generally favorable about "The South Seas," but there was, ultimately, little encouragement for trying the midwestern states again. Melville only performed in ten cities during the 1858-59 season, and although he made more money than he had the year before in sixteen cities and was apparently becoming more comfortable on stage, he had not done well enough to expect a new career as a lecturer—particularly if he had to rely on pleasing western audiences. In Michigan, Bayard Taylor wrote a parody of "The Raven," comparing the bird's "nevermore" and the student's vain efforts to escape, to fans and agents with speaking invitations rapping at his chamber door and allowing him sleep "nevermore." Melville had no such troubles to complain of.[18]

In addition, Melville had not managed to generate any new demand for the once-popular south sea narratives. He was already working on poetry in the summer of 1859, and, without much enthusiasm, looking into possibilities for publishing a first volume of verse. He also prepared a third lecture, as a more practical venture. However, to cancel his debts to his father-in-law, which Melville had been accumulating ever since his marriage, he agreed to deed his farm property to his wife, amounting to an admission of his failure as head-of-family and provider. The consensus among the family—Herman's too, probably, though he resisted it—was that he would have to find steady work and give up uncertain literary pursuits. He approved of efforts to find him a political appointment, although he did not actively pursue one.[19]

Lecturing was still his only immediate source of income, but his third season was the least profitable of all. Melville was so outwardly depressed and physically weak that family members suggested a vacation at sea again in 1860, as they had the year before he tried lecturing. He planned to go through the South Seas again; ironically, he became sea sick on the voyage out—the only time this had ever happened to him—and he cut short the voyage. When he landed in San Francisco, he decided to go home immediately. In fact, Melville received an invitation to read there, which he declined, although he had manuscripts with him.[20] By coincidence, Melville's final realization that he would have to stay home and work at some routine came just before Mark Twain first lighted out for the western territories and began to find an idiom for himself as a world traveler and writer.

Melville's difficulties as a popular writer have been exaggerated and romanticized. He never was as much the deliberate outcast as some readers have thought; he never was an Edgar Allan Poe or Charles Baudelaire, writing what he thought profound to spite a public who never could appreciate him.[21] Even Melville's most critically-condemned and publicly-ignored books, *Pierre* and *The Confidence-Man,* were disappointments because he had thought that they would sell. Melville did not imagine himself essentially at odds with the bourgeois reading public, although he did finally realize that what talent he had as a writer would never make him rich or even provide a sole means of support. His lecturing, like his last romances, was a disappointment to Melville because he believed that it might work. But he found out, once again, that he did not have what it took to please the crowd.

Notes

[1] See letter to Hawthorne in *Moby-Dick,* ed. Harrison Hayford and Hershel Parker (New York: Norton, 1967) 556-60.

[2] Merrell R. Davis, "Melville's Midwestern Lecture Tour, 1859," *Philological Quarterly* 20 (1941): 57, suggests that Melville's South Sea lecture lacked spontaneity because he had no fresh observations on his experiences; and Merton M. Sealts, Jr., *Melville as Lecturer* (Cambridge: Harvard UP, 1957) 100-01, 121-23, believes that Melville "was thoroughly tired" of trying to rework the popular subject and, furthermore, had "grown alien to mid-century America."

[3] See comments from his cousin Henry Gansevoort in Jay Leyda, *The Melville Log: A Documentary Life of Herman Melville, 1819-1891,* 2 vols. (1951; rpt. New York: Gordian Press, 1969) 2: 600-01; Alfred Kazin, *An American Procession: The Major American Writers from 1830 to 1930—The Crucial Century* (New York: Knopf, 1984) 131-60; and Sealts 61.

[4] Leon Howard, *Herman Melville: A Biography* (Berkeley: U of California P, 1951) 211, 256-57.

[5] Howard 258-60; and Sealts 58.

[6] Newspaper reviews are taken from the collections of the State Historical Society, Madison.

[7] See Ralph M. Aderman, "When Herman Melville Lectured Here," *Historical Messenger* 9.2 (1953): 3; Carl Bode, *The American Lyceum: Town Meeting of the Mind* (1956; rpt. Carbondale: Southern Illinois UP, 1968) 174-75; and John C. Colson, "'Public Spirit' at Work: Philanthropy and Pubic Libraries in Nineteenth-Century Wisconsin," *Wisconsin Magazine of History* 59.3 (1976): 192-209.

[8] Bode 168, 175.

[9] Bode 98, 166-68; Davis 52-53; and Sealts 61, 83-84.

[10] Kathleen Warnes, "Milwaukee: The German Athens in America, 1835-1920," Wisconsin Academy of Sciences, Arts, and Letters Symposium and Conference, Wausau, 25 April 1986. None of the German-language papers in Milwaukee reviewed Melville.

[11] See Sealts 73-74, 94.

[12] Richard Nelson Current, *Wisconsin: A Bicentennial History* (New York: Norton, 1977) 147.

[13] See Bode 217-19.

[14] Sealts 64.

[15] The full text of "The South Seas" is reconstructed by Sealts (155-80). Page references for passages quoted in the test of this essay are contained in parentheses.

[16] Davis 47; Leyda 603; and Sealts 76, 93.

[17] Howard 261.

[18] Bode 218-19; and Sealts 92-93, 99-100.

[19] Howard 262-67.

[20] Howard 267-69.

[21] Kazin calls Melville a "captive to the commercial capital," New York City (137), and recalls that Sam Melville, the "Mad Bomber" killed at Attica State Correctional Facility in 1971, took his name for Herman, whom he identified with revolution (158). In addition, Edwin Haviland Miller, *Melville* (New York: Persea, 1975) 295, says that Melville could not resign himself to giving audiences what they wanted.

SIMULATION IN LANDSCAPE PLANNING AND DESIGN: THE ART OF VISUAL REPRESENTATION

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This paper examines the subject of visual representation in landscape planning and design by subdividing the subject into several related sub-topics including its relationship to environmental impact assessment and contemporary problem-solving, the benefits associated with simulation use and how that has led to the development of a simulation course at the University of Wisconsin.

A BRIEF HISTORY

Throughout history man has used visual representations such as drawings, paintings and three-dimensional objects to simulate visual modifications to his world. Some of the earliest simulations used by environmental planners and designers were pottery models built during the 1st and 2nd centuries AD in China. These miniature representations illustrating ornate wall and roof details were used to guide the wooden architecture of the time.[1] Other early simulations included maps, plans, sections, elevations, sketches and perspective drawings—techniques that are still in much use today. An early development by the landscape architect Humphrey Repton used illustrations hinged in such a way that both existing and proposed environmental conditions could be displayed at the same time. This technique using "slides" of proposed improvements could be flipped up to cover only those parts of the landscape to be changed. Repton believed this provided a far more effective means than maps or plans to help clients visualize the effects of environmental changes.[2] Similar overlay techniques are in wide spread use today and serve as the basis for much of the work produced by planners and designers.

Early techniques like Repton's slides which were dependent upon pen and ink, pencil, and watercolors were subsequently augmented by photography as a tool for visual representation. Initially in the nineteenth century, on-site eye-level photography became popular and later with the advent of World War II, aerial photography became available and gained widespread use. More recent advancements including the use of photo-mosaic and stereo-pair photography have greatly facilitated large scale analysis of land areas for design and planning.

Recent technological developments have made new visual tools available to land planners and designers including movies, video and computers for analysis and communication. On the horizon are the use of highly realistic computer-generated animations similar to those used in many recent "box office" hits.

This discussion might lead one to believe that there is an ever increasing reliance on the use of visual simulations in landscape planning and design. Such a conclusion would be only partly true. As noted, the practice of landscape planning and design has always relied on the use of simulations although it is now adopting the use of more sophisticated technological innovations.

The growing use of more complex and sophisticated simulation techniques in landscape architectural practice and research poses a new set of challenges for professionals. These include keeping abreast of new developments and understanding their strengths and weaknesses, limitations and opportunities, and knowing where to integrate them into the design and planning process.

Simulation and Environmental Impact Assessment

One of the most important single actions that has been devised to elevate the importance of environmental management and visual simulation in this country, was enactment of Public Law 91-190, the National Environmental Policy Act (NEPA) in 1969. The purposes of this legislation were:

> "To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and national resources important to the Nation; and to establish a Council on Environmental Quality. (42 U.S.C. 4321)."[3]

But what does this have to do with visual simulation?

The Act goes on into additional detail as exemplified in the next excerpt:

> "(b) in order to carry out the policy set forth in this Act, it is the continuing responsibility of the Federal Government to use all practical means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the nation may—
>
> (2) assure for all Americans safe, healthful, productive and esthetically and culturally pleasing surroundings;"[4]

The responsibility for carrying out this mandate at the Federal level is stipulated in Sec. 102 of the act as follows:

> "Sec. 102
>
> (A) Utilize a systematic interdisciplinary approach which will insure the integrated use of natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment."[5]
>
> The scope and purpose of NEPA extends beyond an analysis of the impact of proposed actions upon "esthetically and culturally pleasing surroundings."

One Federal agency that has taken this responsibility of exploring the area of visual impact seriously is the Bureau of Land Management, Division of Recreation and Cultural Resources. In 1980, a well illustrated report was published under the title VISUAL RESOURCE MANAGEMENT PROGRAM.[6] Whereas the document deals with the broader subject of visual resource management, one section is devoted entirely to "VISUAL SIMULATION TECHNIQUES." Several visual simulation techniques are described and illustrated and focus on such projects as highways, dams, power plants, and overhead transmission line structures to mention a few. In addition to these subjects, illustrations of various techniques have been provided as concrete examples of the effectiveness of various techniques to simulate proposed actions of various types of landscape conditions.

The leadership that was provided at the national level through enactment of NEPA was echoed by various states including Wisconsin. In 1971, Assembly Bill 875 was enacted and became known as the Wisconsin Environmental Policy Act (WEPA). Upon reading WEPA, the reader is struck by the similarities in purposes and language with NEPA. Whereas NEPA mandates environmental impact assessment by Federal agencies, WEPA focuses upon the mandate of conducting environmental impact assessments on certain specified actions that could have deleterious affects upon the environment of Wisconsin.

Unfortunately, the administration of WEPA has not been accompanied by consistent applications of visual simulations as a means of evaluating the acceptability of certain visual impacts that accompany developmental actions in Wisconsin.

The Role of Simulation in Contemporary Problem-Solving in Wisconsin

A number of recent case studies illustrate the usefulness of visual simulations in environmental decision-making. These applica-

Fig. 1a. A typical streetscene in a Wisconsin Community.

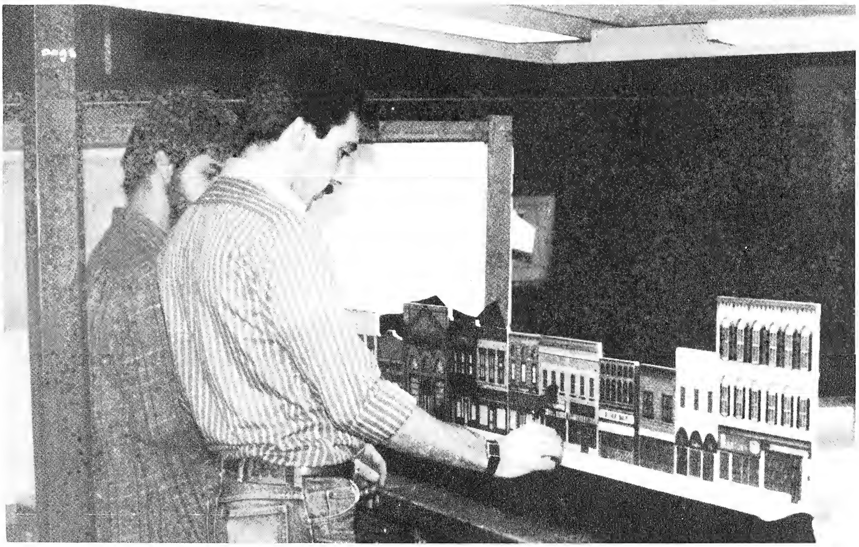

Fig. 1b. Three-dimensional model simulating proposed streetscene changes.

tions range in scope across political levels and the variety of available simulation techniques.

Wausau Sign Ordinance—

Hand-drawn simulations were recently developed for use by a grassroots organization in Wausau, Wisconsin to illustrate the impact of a proposed sign ordinance. From 35 mm slides of several urban streetscapes, illustrations of the existing scenes without signage were generated. Two drawings were then superimposed on the original illustrations; one depicting existing sign conditions, the other showing the changes necessary to comply with the proposed ordinance. This technique provided a quick and efficient means for illustrating the effects of the proposed mandate.

UW Band Practice Facility—

As part of a University of Wisconsin class exercise, landscape architecture students prepared three-dimensional simulation models to provide design recommendations for a proposed university band practice shelter. This proposed facility, to be built in an area providing unobstructed views to the bordering lake and along a notable segment of Madison's Park and Pleasure Drive system requires a design that is responsive to the area's character and sensitive features.

Again working from 35 mm slides of the area, a stage-set apparatus was built in which several scale models of proposed design solutions for the practice facility were placed. This combination of elements provided an opportunity to evaluate the models in terms of position, form, color, and texture against the "backdrop" of the existing context. As a result an exhaustive list of design recommendations were tested, evaluated and established before any construction took place.

Community Applications—

In the Fall of 1985, fourteen students in Landscape Architecture focused upon downtown Lake Geneva, Wisconsin. In this advanced design studio, the project scope encompassed social-demographic considerations, development of a land-use and open-space master plan and analysis and design of retail structures in the downtown district. Detailed elevation drawings, depicting how the appearance of each building could be improved, were created by the students.

An outgrowth of this project was a large model representing recommended improvements for each building in the four block area of the downtown (Fig 1a,b). The model, representing each of the eight blockfaces, was elevated to shoulder height, so that people could move through the model and experience how the downtown would look if recommendations were implemented. The model was also video taped by placing the video camera on a cart with the operator, and moving the cart through the space between each block of the model to represent the dynamics of driving through the downtown.

Overhead Transmission Lines—

Several years ago, B. Murray and B. Niemann (Professor, U.W. Madison, Department of Landscape Architecture) provided testimony concerning whether overhead transmission lines should be constructed in the vicinity of the Cross Plains unit of the National Ice Age Reserve (the Reserve). Among the numerous exhibits used were illustrations depicting the visual impact associated with overhead lines. Utilizing photographs of the site, with wood poles in place, including installed insulators, the electric lines were rendered in the photograph. This simulation served to illustrate how overhead transmission lines would alter views to and from the Reserve from certain vantage points within and around the Reserve. Graphite pencils were used to illustrate the variegated play of light on the surface of the lines. At certain times during the afternoon, light would be reflected from the lines creating white lines against a darker background of land and

Fig. 2a. A University of Wisconsin heating plant.

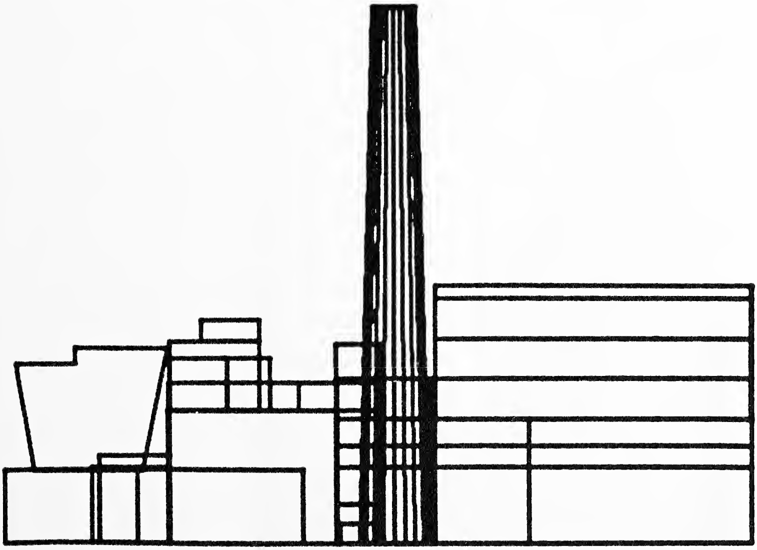

Fig. 2b. Computer-generated image simulating proposed building changes.

vegetation thereby increasing the visibility of overhead lines. The utility was subsequently required to place the lines underground in order to preserve the visual quality of the Reserve.

UW Emission Control Facility—

To illustrate the effectiveness of dynamic simulations in environmental planning, computer generated graphics were used to illustrate the addition of an emissions control system to an existing heating plant on the University of Wisconsin campus (Fig 2a,b). These images provide the viewer with the opportunity to quickly add or subtract the proposed addition to a plan, elevation or perspective view of the present structure. In addition, the computer images could be rotated to give the viewer the impression of "walking" around the structure. Such a dramatic technique not only serves the viewer with a vicarious experience of the setting but gives the designer the capability to quickly manipulate and evaluate several alternative solutions.

Benefits of Visual Simulation

While the reasons for using visual simulations and some of the past and present uses have been discussed, little has been said about the benefits derived from such work.

The principle objective associated with simulation use is the ability to evaluate alternative futures and proposed actions. For example, what will the environment look like, what will be the relationship of spaces, and what materials, colors, and textures should be used to complement the existing landscape?

Simulation is intended to provide valid, reliable, and useful information about the visual landscape to those who manage the environment, who promulgate and implement policy, and who plan and design physical changes in the environment. In other words, simulation is intended to provide information to improve the quality of decision-making with reference to environmental management as well as to change and modification. Simulation can also help identify and specify problems that will emerge that might otherwise be ignored or misunderstood. It can provide information based on empirical data rather than on guesses and intuition, thus providing an empirical basis for the establishment of new approaches to environmental planning, management and design.

Whenever growth occurs, environmental modification will occur. Hundreds of thousands of new environments are changed or created each year, ranging from individual housing developments to clearcutting on the National Forests. Evaluating all such environments after alteration would be an enormous costly and inefficient undertaking. One way to gain a better understanding of the impact of these changes on our visual environment is through simulation. Simulation studies provide a means for assessing the nature of the environmental impact before a project begins. This information makes it possible to modify, fine-tune, or abandon the proposal before any irreversible action takes place. Thus, simulation provides a cost-efficient means to evaluate a range of solutions and their associated costs.

Simulation can also be used to improve communication problems between and among participants involved in the design/planning process and enhance public participation by facilitating heightened understanding of potential impacts. In many cases, simulation is perceived as an integral part of the planning/design process. There are several reasons for this. First, it provides an early opportunity for interested parties to participate directly in the design/planning process. Second, it gives the user the ability to utilize the simulated options as an educational tool, informing clients as to what is possible and how the solution is responsive to the project objectives—that is, to their needs and wishes. And third, it gives both the client and the designer/planner an opportunity to explore the meanings each derives from the several options.

Visual Simulation Course: Theory and Practice

It is apparent from the preceding sections that public policy legislation and review has resulted in the creation of instruments that require an analysis of environmental, economic and social impacts as a prerequisite for granting authority to proceed with certain types of development. It is also evident that visual simulation has been and is being incorporated into some decision-making issues. Lastly, the point has been made that benefits are derived from carrying out visual simulations that may either stand alone or accompany other aspects of environmental impact assessment. If one can accept the relevance of visual simulation, a cogent question requiring an answer is "how are individuals prepared to perform visual simulations through public and private entities and for many different types of clients?" Universities can provide an important resource for advancing the science of visual simulation. One response can be found in the Department of Landscape Architecture at the University of Wisconsin-Madison. In the Spring of 1986, a course entitled "Visual Simulation in Landscape Planning and Design" was offered for the first time. The purpose of this required course is to involve graduate students in the ethical, theoretical and practical dimensions of the art and science of visual simulation.

Conclusion

The profession of landscape planning and design is experiencing the growing use of more complex and sophisticated techniques for visual representation. As more techniques are developed and refined, landscape simulation will continue to be used as a means for evaluating the visual effects of human-altered environments. At present, however, the administration of public policies requiring visual impact evaluations such as NEPA and WEPA are not accompanied by the consistent use of simulations. This poses a new set of challenges for planning and design professionals. In response, the Department of Landscape Architecture at the University of Wisconsin has introduced a new course designed to help prepare and inform students about the advantages and potential pitfalls associated with visual simulation work. The authors believe it is evident from the case studies reported that the University has established a solid foundation in this important area in the education of future landscape planners and designers.

Notes

[1] Norwich, J. J. 1979. *Great Architecture of the World.* New York: Bonanza Books.

[2] Goode, P. 1984. Humphrey Repton. Landscape Planner: Avant la lettre. *Landscape Architecture.* 74(1):54-56.

[3] National Environmental Policy Act of 1969.

[4] *Ibid.*

[5] *Ibid.*

[6] Visual Resource Management Program. 1980. U.S. Government Printing Office: 0-302-993.

WOMAN AS EROS-ROSE IN GERTRUDE STEIN'S *TENDER BUTTONS* AND CONTEMPORANEOUS PORTRAITS

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As the blind glass of the opening still-life of *Tender Buttons,*[1] Gertrude Stein presents herself like the Greek seer Tiresias. She is our prophet, our Sibyl. And like Tiresias and the typical Sibyl, she is of ambiguous sex. While clearly female physically in real life, Stein thinks of herself as male in the great poetry of her 1913 *Tender Buttons*—one of the keys to this work that many baffled readers have missed. Earlier, in fact, in Stein's lesbian-autobiographical novel *Things As They Are,* Adele/Stein actually exclaims at one point,

> "I always did thank God I wasn't born a woman."

In "Objects," the second section of the triad "Objects," "Food," and "Rooms" that comprise *Tender Buttons,* Stein intends to view simultaneously, both subjectively and objectively, the world "out there." Understandably, things nameable emerge on her writing tablet in a complicated form. One half of Stein partakes of, yet criticizes, the hard handsome glory of the male spirit dominant in the second still-life of Tender Buttons, GLAZED GLITTER. But Stein's second half feels the debasement, yet soft sensual appeal of the female, seen in anthropomorphic, dualistic thinking as matter itself, and objectified in A SUBSTANCE IN A CUSHION, the third still-life of "Objects."

Characteristically, while the Sibyl takes an intellectual stance, she is not sexless; instead, knowing herself erotically drawn to women rather than to men, she comes into the position of Sappho. And the Sapphic passion—in Gertrude Stein's case her desire for Alice Toklas—is one of the ecstatic messages expressed cryptically in the tiny exploding still-lifes and in similar imagistic passages within the more abstract meditations of *Tender Buttons.* For while the sheer poetry of WATER RAINING, A PETTICOAT, RED ROSES, A SOUND, and multitudes of other little poetic bursts can be interpreted in a single dimension as statements about Pragmatic philosophy, often they also present fleeting insights into the charms of the female human being; and these erotic preoccupations emerge in phrases, lines, sentences, paragraphs, everywhere, just as Freud in *The Interpretation of Dreams* found human desire all-pervasive in the human unconscious. And if Gertrude Stein, Sibyl and Sappho both, thus mixed abstract philosophy with concrete poetry, it was inevitable. For Stein's chief endeavor in writing *Tender Buttons* was to effect a reconciliation between the competing claims within her of thinking and feeling, of the dualism in her own subjective being that she projects onto the shifting external objects of her contemplation.

To study Gertrude Stein's imagery presenting woman as aesthetic object in *Tender Buttons,* I will for the moment concentrate, with grossly simplified poetic analysis, on a single poem, one that seems among the least obscure and is certainly among the most charming.

> A PETTICOAT
> A light white, a disgrace, an ink spot, a rosy charm. (471)

There happen to be exactly 17 syllables here, as in the Japanese haiku, if one counts the title as part of the poem—which of course one does not do in haiku, since haiku usually lack titles. What is important is that, like haiku, Stein's poem uses the *juxtaposi-*

tion of ideas and the connotations of words to create the message, rather than cause-and-effect logic. At first glance A PETTICOAT appears to promise a series of qualities defining a woman's undergarment, but a second look shows a certain light-hearted confusion—for an ink spot is not typical of petticoats! An ink spot is a sign of soiling, however, casting a blight on the white purity of the woman's intimate apparel, and perhaps by association, therefore, with the virtue of the woman's body beneath the petticoat too? Or is the implication that using ink, perhaps writing or the profession of a writer, damages a woman's femininity, signified by her rosily charming undergarments? The poem insists that some disgrace is involved in petticoats, or at least in one of these items. There is clearly what one almost always has in Stein: a riddle, a mystery—even an implied narrative.

From a strictly external view, the poem has the air of a perfect little song. The accented syllables of the title A PETT′I-COAT′ and of the last phrase "a ro′sy charm′" are identical, as are the intervening three phrases, "a light′ white′" and "a dis′-grace′" and "an ink′ spot′" so that the whole can be thought of as either linear or circular, or both. And when finally the lost pattern of the title comes back in the final phrase, we breathe a sigh, fulfilled by the perfection. Assonance working behind the scenes along with alliteration gives the flounces needed to create the pretty petticoat.

Of course there is much more to A PETTICOAT than mere sound-charm. The sound-charm (magical incantation?) reflects the sense charm, ready to be fathomed. A petticoat is a little, light thing, a "female" thing as opposed to a big heavy garment like a male's overcoat; it is, moreover, an undergarment, an appropriate metapor for the more protected sex. Read in the context of its surrounding poems in *Tender Buttons,* AN UMBRELLA (an object which also flares out roundedly) and A WAIST (here described as gliding in slim charm like a star), the femininity of the petticoat is strengthened all the more.

A PETTICOAT begins with the phrase "A light white." What is the meaning here? The allusion may be to *difference* itself, with the reader's attention drawn to the fact that "white" is not merely an abstract idea, but exists in many different particular white things. Or perhaps as she often does, Stein is transferring a word or part of a word from its own place to another; and if she is using such a device here, "a light white" might be "a white light," perhaps a spotlight, or just a white dot or spot to contrast with the third phrase of this still-life, "an ink spot." As it happens, the still-life directly preceding A PETTICOAT ends with the word "dot." Such trails, like the fact that the poem directly following also contains the word "disgrace," must be followed as one unwinds Stein's twisting threads. Some appear less significant than others, but there is no avoiding the all-pervading color symbolism of *Tender Buttons.*

Returning to the idea of different shades of white, we might discover "cream" as one of the possibilities. Cream is not pure blazing white, but a yellowish-white color; it happens to be one of Stein's code-words for the delightful and fulfilling life. Associations with cream—milk, ice cream, custard, cows, the country, meadows, milking stools, even roast beef (the cow cooked) in Stein's writing signify hedonistic pleasure, both sexual and gustatory ecstasy: the joys of living. Hedonism and delicate, flippant joy in hedonism were expressed to perfection by writers in Stein's favorite period in English literature. Robert Herrick also wrote of petticoats[2] and the disgrace of "a sweet disorder in the dress." Stein's vocabulary in A PETTICOAT, both in word and thought, is interestingly similar to Herrick's, and his telling young women to gather rosebuds while they may in "To the Virgins to Make Much of Time" reminds one of Stein's virgin in IN BETWEEN, which deepens the erotic level of A PETTICOAT (brackets below give my suggested reading):

IN BETWEEN

In between a place and candy is a narrow foot-path that shows more mounting than anything, so much really that a calling meaning a bolster measured a whole thing with that. A virgin a whole virgin is judged made and so between curves and outlines and real seasons and more out glasses and a perfectly unprecedented arrangement between old ladies and mild colds there is no satin wood shining. (472)

[''In between a place'' (place of delight; also, place is a chime for ''Alice) ''and candy'' (the sweet of desire) ''is a narrow foot-path'' (a difficult place to travel) ''that shows more mounting'' (reference to mounting excitement, or mounting as taking a sexual position) ''than anything. . . .'' The ''bolster'' can be ''the bold sister''; also, might be an age reference to Gertrude and Alice, several of which occur within *Tender Buttons,* whom Gertrude alludes to as ''yellow'' or ''mellow'' or as ''mutton'' rather than lambs in MUTTON; this poem in fact ends on the age question, with allusion to Gertrude and Alice's ''perfectly unprecedented arrangement,'' which differs from one made between ''old ladies'' (sexually cold, presumably) and the hotter one between women like Stein and Toklas as ''mild colds'' (only mildly olds). ''A whole virgin'' (an intact virgin) is judged ''made'' (maid; also, made a virgin, but ''undone'' voluntarily). Stein plays throughout with the idea of ''wholeness,'' ''holeness,'' and perhaps even ''holiness'' and ''evil'' if the ''satin'' in the last phrase is Satan.]

Another suggestive little scene, here of intercourse and its aftermath, occurs in RED ROSES, the poem directly preceding IN BETWEEN:

A cool red rose and a pink cut pink, a collapse and a sold hole, a little less hot. (472)

[Something ''red'' (code word for woman, with the ''something'' here her private part; could also refer to male's organ) that was ''cool'' (not stimulated) ''rose'' (became excited and swelled; if male organ, became erect) while ''a pink'' (one person's pink part, lips or nipple or finger-''pinkie'' or private part) ''cut'' (inserted itself into) ''pink'' (another's intimate body part). There was a collapsing (emission and/or deflation), and ''as for the old hole, it was a little less hot after that''; or there may even be an obscene reference to ''old ass hole.'' (I will not go into matter here, but Stein matches Joyce's early scene in *Ulysses* that shows Leopold Bloom performing his bowel functions with her *Tender Buttons* poems A BROWN and A PAPER.]

The poem that follows IN BETWEEN and RED ROSES is called COLORED HATS, and may be one of the clearest references in *Tender Buttons* to the trip to Spain that Stein and Toklas took as Gertrude ran away from the strained situation with Leo at their apartment at 27 rue de Fleurus and tried to decide what to do.[3] Avila was one of the places that Stein and Toklas visited and loved, and Avila is a place that happens to be famous for its colored hats. In *Avila* Camilo José Cela writes

In the regions of Barco de Avila, Piedrahita, Hoyocasero—and occasionally in the city itself—we can still sometimes see women wearing the pleasing *gorra* of curled straw. It is a tall helmet-like hat adorned with different coloured wools . . . of material coloured according to a woman's condition. If she is a spinster the material is green, red for a married woman and black for a widow. It is curious to notice how often in their dress we see Castilian women wearing some adherence to colours indicating virginity, married state or widowhood. . . .[4]

With this in mind, one reads Stein's COLORED HATS with new understanding, finding in the poem meaningful references to women's married-state conditions like pregnancy (''broad stomachs'') and childbirth (''the least thing is lightening'') and to their virginity-associated conditions like menstruation (''custard whole''). One even sees a reference in COLORED HATS to the virgin ''Saint Teresa, the ''Little Flower'' who is everywhere worshipped in Avila, as well as a jocular reference to Louisa May Alcott's virginal *Little Women* and perhaps even to Pearl, the sinning Puritan Hester Prynne's bastard child. (In this quotation my interpretations occur within the quoted poem itself, enclosed in brackets. To making reading easier, Stein's own words are italicized.)

COLORED HATS

Colored hats are necessary to show that curls ["girls," indicated by a rhyming word and also by association of "girls" and "curls"] *are worn* [worn out, exhausted—what Stein had observed as a medical student helping to deliver babies] *by an addition of blank spaces* [extra spaces, thus pregnancy], *this makes the difference between single lines* [virgin's lines] *and broad stomachs, the least thing* [the baby] *is lightening* [makes the mother weigh less when it is born], *the least thing makes a little flower* [a little flow-er of water and blood, as well as a little flower or bud-baby, one saintly like St. Teresa] *and a big delay* [de-lay, pun of the lengthy laying-in process of birth] *a big delay that makes more nurses than little women* [children, virgins, also women little again after childbirth] *really* [materially, factually] *little women. So clean is a light that nearly all of it shows pearls and little ways* [weighs, weights, reference to matter]. *A large hat is tall and me and all custard whole.* (473)

The allusion to children in COLORED HATS, the little things that lighten broad stomachs, is repeated two poems later in A LITTLE CALLED PAULINE, where Stein announces that a "little" (a baby) called by any name whatsoever "shows" (signifies) 1) mothers (half-rhyme with "shudders"), 2) udders (perfect rhyme with "shudders"), 3) shudders (literal quivers in Stein, who while assisting in the delivery of babies as part of her medical training had been so appalled at the process of childbirth):

A LITTLE CALLED PAULINE

A little called anything shows shudders. . . . (473)

To return however, to the comparative innocence of PETTICOAT. Besides femininity, A PETTICOAT features another important Stein theme: her writing. This is the idea behind "an ink spot" (both pubic hair and "ink's pot") which leads ultimately to the relief of "a rosy charm." Alluring in her saucy undergarments, Miss Alice Toklas is a light white or white light beacon. She is also a disgrace if the world sees her as what she is, Gertrude's lesbian lover.

To support this contention and my interpretation of the petticoat poem, let us look at female figures in the portraits written at the same time of *Tender Buttons.* In many of these portraits Alice Toklas[5] is the heroine who comes to "save" Gertrude by her loving support and her erotic charms which awaken Stein to the poetry of life. Naturally, images of woman as eros-rose, Beauty, are more indirect in Stein's *Tender Buttons,* which seeks to personify through objects, than in her portraits, which attempt to render living people. The images of erotic woman in the portraits, while still disguised through obfuscating language, *should* be relatively easy to fathom, but for many critics this has not been the case, and many do not locate Alice Toklas behind all the multiple-image temptresses "Susie Asado" and "Preciosilla" and as the fellow gypsy with Gertrude Stein in "A Sweet Tail (Gypsies)." Richard Bridgman even discounts Carl Van Vechten's suggestion that the famous flamenco dancer la Argentina was one of the female images behind these portraits.[6] Similarly, other excellent critics such as Marjorie Perloff in *The Poetics of Indeterminacy,*[7] James Mellow in *Charmed Circle: Gertrude Stein & Company,*[8] and Wendy Steiner in *Exact Resemblance to Exact Resemblance: The Literary Portraiture of Gertrude Stein,*[9] all appear confounded because there may have been more than one dancer seen by Gertrude and Alice in their wanderings in Spain when the portraits were written, or for other overly-specific reasons. However, if one allows that multiple, ambiguous identifications are true, but that behind them all is invariably the figure of Alice Toklas, everything falls into place, and one can relax and attend to Stein's experiments in these portraits and in *Tender Buttons,* where Gertrude Stein tried in words, like her Cubist friends in their medium, paint, to render the rhythms, sounds, shapes, colors of the external world.

In "Susie Asado" Stein gives us, in one erotically pulsing woman, a nursery rhyme tea hostess, a chirping bird, a Japanese geisha, a Spanish dancer clicking her heels down in a silvery-lit Madrid night spot or "cellar," a witch from MacBeth, an incubus riding a victim, Alice Toklas as Gertrude's "sweetie" or "Sweet T[oklas]" serving tea at 27 rue de Fleurus, and many other versions of all the beckoning desirability of Nature seen as female Being. Here in its entirety, with selective decodings, is "Susie Asado," wherein Stein presents one of her most vivid images of woman as enchantress, yet combines this with a possible philosophic questioning about the nature of matter and even a suggested solution to the problem of human suffering (again, brackets are my hints on a reading, and to aid the reader I have italicized Stein's own words):

> *Sweet sweet sweet sweet sweet tea.*
>
> *Susie* [Jewsy, choosey, choose me] *Asado* [as I do].
>
> *Sweet sweet sweet sweet sweet tea.*
>
> *Susie Asado* [Mikado, the Japanese geisha reference].
>
> *A lean on the shoe* [the Spanish dancer, perhaps la Argentina] *this means slips* [lips] *slips hers* [slippers].
>
> *When the ancient light grey is clean it is yellow, it is a silver* ["la Argentina," "the Silver one"] *seller.*
>
> *This is a please* [request] *this is a please* [appease], *there are the saids to jelly* ["jelly," a black jazz word referring to Jellyroll Morton who played piano in a brothel, was a code word for intercourse in Stein's story in *Three Lives* about a black girl named Melanctha; also here are the jelly and the "he said, she said's" of the ladies' tea party]. *These are the wets* [wets, sweets] *these say the sets to leave a crown to Incy* [inky].
>
> *Incy is short for incubus.*
>
> *A pot* [pot, spot, belly]. *A pot is a beginning of a rare bit* [rarebit] *of trees* [cheese]. *Trees* [also tease] *tremble, the old vats are in bobbles* [bubbles, bubbling vats of Macbeth's witches, women as creators of magical brews], *bobbles which shade* [spade] *and shove* [shovel] *and render clean* [rend her clear], *render clean must.*
>
> *Drink pups* [drink ups: kisses, suckings].
>
> *Drink pups drink pups* [The doubling here, as in other Steinian words and phrases and lines, creates mutual participation] *lease a sash hold, see it shine and a bobolink* [woman as bird, a favorite Stein association] *has pins. It shows a nail* [an "ale" as intoxicating beverage brewed by witches; also an "ail," a pain of sentient desire].
>
> *What is a nail* ["a nail" can be "an ail," so that Stein asks, "What is an ail?" or "What is a feeling of pain? What is sensation?" These are favorite questions of the Gertrude Stein who studied philosophy with William James. Also, these words may be read in another Steinian way, as making a statement of definition of the word "what," or "matter, substance." Stein tells us in that way of reading the sentence, "'What' is an ail," meaning that the philosophic questions concerning "whatness, substance," are an ail, a painful problem, for us humans].
>
> *What is a nail* [Stein repeats her phrase, underscoring her point, or forcing us to shift ground, cubistically, to constantly new views of the words' possibilities. Stein could be asking simply about a materially substantial "nail" with a specific function, a pointed object the purpose of which is to join substances together]. *A nail is unison* [union; Stein answers her own question, as she will ultimately in *Tender Buttons,* by combining intellectual meaning and sentient drives in humans and all nature. The answer favors unity, yet there are a plurality of strands being united, not a dualistically conceived mutually-exclusive spirit or matter. The solution is Pragmatic, joyously sensual, celebrating eros and woman]. *Sweet sweet sweet sweet sweet tea* [Stein ends by drinking the witches'

delicious poison offered by her bewitching Alice]. (549)

"Preciosilla" is another rhythmic marvel, ending with the same dark-skinned ("toasted") Susie, Gertrude's "Jewsie" (her pet name for Alice), her "precious silly," again her favorite "cream" dish or dessert after she has told brother Leo, now no longer a member of the household but an unwelcome guest, to "Go":

> . . . diamonds white, diamonds bright, diamonds in the in the light, diamonds light diamonds door diamonds hanging to be four, two four, all before, this bean, lessly, all most, a best, willow, vest, a green guest, guest, go go go go go go, go. Go go. Not guessed. Go go.
> Toasted susie is my ice-cream. (551)

The dancer in the companion portrait to "Susie Asado," "Preciosilla," does more than dance. Bait, Preciosilla's clothes are torn off, and she is urged towards a "single mingle," union, in the third paragraph:

> "Bait, bait, tore, tore her clothes toward it, toward a bit to ward a sit, sit down in, in vacant surely lots, a single mingle, bait and wet . . ." (550)

This is obscene, as is the title of "A Sweet Tail (Gypsies)" obscene. And again in "A Sweet Tail" there is depicted what can be construed as an explicit scene of intercourse between two women ("curves"). "Hold in that curl [girl] with a good man," Stein tells herself, assuming the male point of view, and teasing herself and us with all sorts of jokes and puns and meaningful suggestions involving holes in cheese, and pinnings, and a petticoat beloved, whom she urges to "come"; the portrait of the wandering lovers embracing even ends with the "dear noise" of orgasmic bliss:

> *Curves. Hold in the coat* [goat, go at]. . . . *Hold in that curl* [girl] *with a good man. Hold* [hole] *in cheese. . . . A cool brake* ["break" with Leo, again the invisible third party] . . . *Come a little cheese* [*please*]. *Come in to sun with holy pin* [hole leaping] *and have the petticoat to say* [save] *the day . . . a dear noise* [an orgiastic moan, an "Adear" or "Ada(r)" noise, Ada being a code name for Alice in Stein's writing]. (571-74)

Whether as the synecdochic petticoat who brings rosy charm at last to a disgraced Gertrude; or as the "Ada" who inspired Gertrude to write a loving portrayal of herself in Stein's very first portrait; or as the "she" who comes bringing salvation to Gertrude in the revelatory portrait "Two: Gertrude Stein and Her Brother," which documents Gertrude's and brother Leo's falling-out; or as the glittering dancer "Susie Asado" or "Preciosilla"; or as Gertrude's fellow expatriate in Spain, one of the pair of Wandering Jews in "A Sweet Tail (Gypsies)"—in whatever shape or form she assumes, always behind Stein's Sapphic and Sibyllic images of women at the time of *Tender Buttons* and the companion portraits blooms the eros-rose Alice Toklas.

Notes

[1] See *Tender Buttons* in *Selected Writings of Gertrude Stein* ed. by Carl Van Vechten, New York: Random House, 1962, 459-509. An excellent preliminary analysis of *Tender Buttons* can be found in Richard Bridgman's *Gertrude Stein in Pieces.* New York: Oxford University Press, 1970. To understand the thinking of Gertrude Stein, however, one should read William James' *Pragmatism* along with *Tender Buttons,* for the philosophy of James, Stein's teacher at Radcliffe, colors her thought throughout. One of the best articles on *Tender Buttons* is Neal Schmitz's "Gertrude Stein as Post-Modernist: the rhetoric of *Tender Buttons,*" *Journal of Modern Literature,* 3 (1974), 1203-1218.

[2] Herrick's "Delight in Disorder" in The *Literature of England,* 5th ed. 1, Ed. George K. Anderson & William E. Buckler. Chicago: Scott Foresman & Co. 1958. 1007.

> A sweet disorder in the dress
> Kindles in clothes a wantonness. . . .
> A winning wave, deserving note,
> In the tempestuous petticoat. . . .

Like Stein, Herrick is suggestively fond of feasting with cream and other goodies. In "The Wake" (an annual parish festival) he urges his beloved to "Come, Anthea, let us two/Go to feast, as others do," for "Tarts and custards, creams and cakes,/Are the junkets still at wakes . . ." 1005-6.

The inclusion of this note on a poet from English literature gives me the opportunity to point out how deep were Stein's knowledge of, and love for, this literature and the English language itself, which is why I chose to cite a large historical compilation rather than merely a volume of Robert Herrick's poetry. Stein read avidly and constantly in English literature, and the riddles of early English literature, in fact, provide one key to Stein's writing style, as do the classical rhetorical devices found so abundantly in Stein's particular passion, Shakespeare.

Stein's language experiments, it is true, usually follow thoughts metonymically rather than metaphorically, and so she often does the opposite of what medieval allegorists and nineteenth century Symbolists did. Understanding this is one of the keys to understanding Stein's writing. Study of Roman Jakobson's article on Aphasia is helpful here: see "Two Aspects of Language and Two Types of Aphasic Disturbances" in *Fundamentals of Language,* The Hague, 1956, 55-82, and the use to which David Lodge puts this material in "The Language of Modernist Fiction: Metaphor and Metonymy" in *Modernism 1890-1930.* Middlesex, England, Penguin Books Ltd., 1976. In the end, Stein avails herself of a multitude of possibilities of thought and language extension, and to read her one must adopt an elastic approach.

[3] Carl Van Vechten, *Two: Gertrude Stein and Her Brother and Other Early Portraits 1908-1912.* New Haven: Yale University Press, 1951.

[4] Barcelona-Madrid: Editorial Noguer, S.A., 5th ed., 1964, 26.

[5] Van Vechton's *Selected Writings* contains several of the Toklas portraits to which I will refer, "Susie Asado," "Preciosilla," and "A Sweet Tail (Gypsies)."

[6] Bridgman, 138.

[7] Perloff, Marjorie. "Poetry as Word System: The Art of Gertrude Stein." *The Poetics of Indeterminacy.* New Jersey: Princeton University Press, 1981.

[8] Mellow, James R. *Charmed Circle, Gertrude Stein & Company.* New York: Praeger Publishers, 1974.

[9] Steiner, Wendy. *Exact Resemblance to Exact Resemblance.* New Haven: Yale University Press, 1978.

ASPECTS OF MORALITY IN THE MUSIC OF THE MIDDLE AGES

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I

For discipline has no more open pathway to the mind than through the ear.

Boethius, *De institutione musica*

In his classic study of medieval aesthetics, Edgar de Bruyne identifies St. Augustine as the principal source of transmission of Biblically-oriented aesthetics for the Middle Ages.[1] In the fervor of faith following his conversion, Augustine himself formulated several unprecedented aesthetic theories. His abundant writings about music lead to C. J. Perl's conclusion that, for Augustine,

> music communicates a knowledge about God, indeed the very knowing of God, and moreover, as becomes clear from the manner of expression, it mediates this knowledge more clearly, more directly, than could words by themselves.[2]

This "very knowing of God" is a process involving the interrelation of sound and time, and the regard of the mind toward that interrelation. Thus does the regard—the modes of perception and response—in turn constitute a significant measure of the morality of any culture; the following is a study of that regard in the Middle Ages.

The numerical aspect is the most well-known. The Greek view of the relation between music and numbers, attested to by numerous writers of antiquity,[3] can be seen through Lewis Rowell's neat summation:

> To the Greek mind, the experience of musical rhythm was an outward manifestation of man's biological rhythms and the proper proportions of the world of forms he inhabited. For rhythm to work its effects upon man, it must be intelligible to his sense perception . . . , and his apprehension of rhythms required him to form mental images that resembled the sounds he perceived. In this way he was brought into tune with the world of external forms in a totally balanced, harmonious, mental and physical state.[4]

The mental imagery was number and proportion, as Pythagoras had discovered. But it should be emphasized that rhythm was meant not only as pulse and metre. To the Greeks, music was primarily verse, and rhythm connected music with language.[5]

This aesthetic, "mathematics incarnate in physical form,"[6] was transmitted to the Middle Ages through the enormous influence of the *Timaeus* of Plato (specifically, in the commentary on it written in the 3rd century by Chalcidius) and—more importantly for music—through the writings of Boethius. Boethius asserted the superiority of the speculative over the practical in music—the superiority of *musica disciplina,* as it was by this time known, over *musica sonora.* This division was partly the result of an attempt by Boethius' contemporary Cassiodorus to distinguish the liberal arts (numerous in Greek antiquity, reduced to seven by Martianus Capella in his *Marriage of Mercury and Philology*) by designating those dealing with human affairs (the *trivium* of grammar, logic or dialectic, and rhetoric) as *artes,* the remainder (the numerically-related *quadrivium* of arithmetic, geometry, music and astronomy) as *disciplinae.* All of the *artes liberales* were in antiquity originally known as *propaideumata,* and affinities had existed between them.[7] Indeed, Boethius himself, in his last work, has Philosophy call upon:

> . . . the sweet persuasiveness of rhetoric, which can only be kept on the right path if it does not swerve from our precepts, and if it harmonizes, now in a lighter, now in a graver mood with the music native to our halls.[8]

But there is little doubt that, in Cassiodorus' terminology, the *trivium* was seen as inferior, *artes triviales*—primarily utilitarian and "wholly propaedeutic" themselves to the abstract speculation afforded by the *quadrivium.*[9]

Boethius, through a tripartite division of *musica* into *mundana* (the music of the spheres), *humana* (that of both the body and the soul), and *instrumentalis* (the sound), reinforced this hierarchy, elevating it (perhaps unintentionally) to an aesthetic principle that dominates both the theory and aesthetics of music throughout the Middle Ages. The appeal was to the mind, to *ratio,* through number and the properties of number, through the medieval belief that the mind could perceive images of a Divine Order in an otherwise terrifying and meaningless universe. These images (and all things and ideas were, in the Timaean account, only images: diversities proceeding from an essential unity) could be subjected to speculation (from *speculum,* mirror) by deducing numerical proportions in them—a wholly interior activity of the intellect—and subsequently reflect some aspect of nature's manner of operation within Divine Order. The *speculum* showed how things act when they thus belong to a type.

However, problems arise when we try to determine any kind of comprehensive correspondence between this view of music and the influence it had on both the thought and action of the Middle Ages. "Medieval theory reduced the idea of beauty to that of perfection, proportion, and splendor," wrote Huizinga.[10] It is not at all certain that medieval practice did so. Huizinga goes on,

> many treatises on the aesthetics of music were written, but these treatises, constructed according to the musical theories of antiquity, which were no longer understood, teach us little about the way in which the men of the Middle Ages really enjoyed music . . .[11]

We need not acquiesce in Huizinga's harsh conclusion that "substituting for beauty the notions of measure, order, and appropriateness offered a very defective explanation of it,"[12] in order to see one thing clearly: the aesthetic record is but part of the reality of the medieval musical experience.

One problem is that the aesthetic record reflects, in the main, the concerns of the Church: "Musical sensation was immediately absorbed in religious feeling."[13] This originated with Augustine, himself acutely sensitive to the aural enticement of music, of the "peril of pleasure."

> Yet when it befalls me to be more moved with the voice than the words sung, I confess to have sinned penally, and then had rather not hear music.[14]

Augustine's solution to this moral dilemma was to make of music a metaphor for communication with God. In the Middle Ages, the emotions were seen as the effects of the senses on the mind, and the senses were lowest in the structure of the mental faculties, to be superintended by imagination, reason, and intelligence. And Denis the Carthusian, also aware of the emotional effects of music, was reduced, in an age of increasing Christian domination, to describing them in terms of sin.[15] Christian doctrine was more secure when it could absorb *musica sonora* into *musica disciplina.*

The Greeks had done this too. Sachs wrote that the scholars of antiquity attempted to classify melodies (which originated in improvisation, with little or no thought given to such representations as vibration ratios), calling this classification "a sham legalization of lawlessness,"[16] one that persisted into the Middle Ages, in the form of the church modes. These modes were designed to house pre-existing chant melodies (which "in notation look so neat and equal-tempered"), and all modes relied on the octave to delineate range; the melodies themselves "had no octave at all or at best one that served in a passing capacity."[17]

But doctrine is one thing, devotion another. And if Carrolly Erickson is correct in maintaining that religious devotion in the Middle Ages "followed a rhythm of its own, and did not correspond in any direct way to the maturing of ecclesiastical institutions or to the political victories or defeats of the church,"[18] the capacity of the written record to account for the relation of music to morality is even further reduced.

Another problem quickly follows: the overwhelming proportion of extant medieval art is Church art. In fact, *musica sacra* is all that survives of early medieval music, although Sachs asserted that secular song was both socially and politically more important in the daily life of the time.[19] So the question finally turns into an old one: how much do the treatises have to do with the moral concepts and conduct of their time? If a connection existed between music and morality, even a unity such as obtained between morality and science (through the links of grammar and poetry), it must be looked for beyond the realm of number, in other modes through which the mind perceives and represents the world.

II

Sight is often deceived, hearing serves as guarantee.

Ambrose of Milan, *Commentary on St. Luke*

Two historical events unique to the Middle Ages can help bring the problems into focus. One event was musical: the advent of polyphony in a musical tradition which until the ninth century had been exclusively monodic. "The invention of polyphony was undoubtedly the most significant event in the history of Western music," Richard Hoppin flatly and rightly declares.[20]

The other event, which preceded polyphony (indeed, made it possible), was the advent of musical notation. As part of a larger process involving a gradual shift in the orientation of the medieval mind from a preliterate, predominantly oral-aural mentality to a predominantly literate-visualist one, this phenomenon was cultural in a more comprehensive way. Both can be examined in the light of the other great theory of music handed down by the Greeks, the doctrine of *ethos,* described by Aristotle in the *Politics:*

> . . . melodies themselves . . . do contain imitations of character . . . with the rhythms the situation is the same. . . . From all this it is clear that music is capable of creating a particular quality of character in the soul. . . . There also seems to be a close relation of some sort between the soul and *harmoniai* and rhythms, which is why many wise men say either that the soul is a *harmonia* or that it contains one.[21]

If melodies imitate character, notation imitates melodies; sight imitates sound. What was the origin of music-writing?

The medieval belief, persistent in subsequent eras, was formed by the Gregorian legend during the Carolingian Renaissance. Leo Treitler has facilitated understanding how this legend succeeded in its purpose, by drawing a parallel with the modern view of musical invention and transmission:

> A corpus of music has originated in a certain time and place and through the agency of a particular person [in the one view, Gregory I receiving chant melodies from the dove; in the other, the composer writing under the guidance of divine inspiration]. At the

> moment of its origin it is written down. The repertory has spread through a transmission that has left a multiplicity of versions [in the one view, varying *mss.* of the same chant melody; in the other, differing copies and editions of the same work]. After some time it is observed that the versions do not agree with one another. This is interpreted as the consequence of a process of corruption, and an editorial enterprise is undertaken to restore and establish the original. As standard for the enterprise a source closest to the point of origin, an original version is sought [in the one view, through the efforts of Charlemagne and Alcuin, in the other, through the efforts of the *Urtextherausgeber*].[22]

But Treitler argues that the original purpose of music-writing was descriptive. The earliest extant examples of proto-notation appear to consist of punctuation signs borrowed from script writing placed in relation to the chant text so as to show the singer where to pause, lengthen a word or syllable, inflect the voice, etc., all in relation to a previously known melody. They were visual aids to the memory of sounds, supporting the "performance of a text already known and accepted." The later diagrammatic notation of the anonymous *musica enchiriadis* and the *musica disciplina* of Aurelian of Reôme, both dating from the ninth century, display evidence of the earliest attempts to actually *picture* the sound-space of a melody by placing both the notation symbol (the neume) and the text syllable at points in space corresponding to the pitch location of the melody.[23]

The Gregorian legend was a tool of policy in the ecclesiastical history of the Holy Roman Empire, a tool used in the Carolingian literacy campaign. "The script culture that the Carolingians created is the general background against which the foundation of a notational practice becomes understandable."[24] The campaign itself was theological, the liberal arts now serving *in toto* as propaedeutic to the understanding of the Scriptures. In a realm whose governing was obstructed by numerous vernacular varieties of Latin, to say nothing of native Germanic, Frankish, Slavic, even non-Indo-European dialects, a uniform and standard repertory of chant melodies offered a persuasive, even seductive means to solve the political problem of polyglottism. Codifying the melodies by encasing them in the eight church modes narrowed the tonal unorthodoxy. The establishment of standardized Latin as the language of the Roman Church was brought about in large part through music-writing, a process that made its first appearances about fifty years after the beginning of Charlemagne's campaign. "The occidental notational system is *par excellence* a control system," wrote Charles Seeger, a statement that is applicable on several levels, musical, cultural, political—and thus moral.[25]

But control is not the end of the matter. The evolution of the word from symbol to fact (the former an ancient, even prehistoric awareness inherited by the Middle Ages, the latter wholly foreign to the medieval mind, familiar enough to the modern) can be found condensed in subsequent developments of medieval music notation:

> The idea of a control system is just the right way to think about the role of notation in an oral performing tradition. Yet there is a point beyond which controls operate so closely and so constantly that the notation becomes in actuality a system of direct representation rather than of controls. When it functions that way, notation has realized an ideal that was expressed by writers on music . . . from Carolingian times to the thirteenth century—for [*sic*] explicit notations that could be read off by performers coming to them cold, for prescriptive rather than descriptive notations. . . . When writing is conceived in the light of a complete equivalence between uttered [or sung] sound and written sign it can function as an autonomous mode of direct communication, and no longer just as an aid to memory. . . .[26]

Polyphony had undoubtedly been in the air. It should be emphasized at this point that it is evident, from their manner of discussion, that authors of the early treatises on polyphony—Regino of Prüm, Hucbald, and the anonymous author(s) of the *musica* and *scholia enchiriadis*—were describing something that had existed in practice for some time. Poor ensemble is as eternal as Divine Order, and in a group performance of monody this heterophony, to use the modern euphemism, must frequently have hinted at the possibilities inherent in intentional divergence. The medieval belief that some of the mysteries of nature could not be understood by the intellect alone is reflected in a question asked in the *musica enchiriadis:* why do certain tones sound well in combination, while others do not? A speculative answer is offered, one which, in its deference to the past, typifies the medieval spirit and connects both parts of the Greek tradition:

> There are several writings of the ancients in which it is convincingly shown . . . that the same numerical proportions by which different tones sound together in consonance also determine the way of life, the behavior of the human body, and the harmony of the universe.[27]

Now, Bukofzer could say, "polyphony deserves to be called the image of universal harmony rather than monody."[28]

Polyphony—the deliberate simultanaiety of two or more musical lines—signalled an incorporation of the plurality of the world of sound into an unprecedentedly complex and powerful symbolic of harmony. The ancient belief in this symbolic became audible. Horizontal and vertical truth, never regarded by the Middle Ages as contradictory or dualistic, could be heard. "The discipline of music," Cassiodorus had written earlier,

> is diffused through all the actions of our life. . . . Musical science is the discipline which treats of numbers in their relation to those things which are found in sounds.[29]

Polyphony was not just a new dimension to this, but a fusion: *musica disciplina* become *musica sonora.*

Or confusion? In medieval grammatical and philosophical usage, one sometimes meant the other, i.e., con/fusion seen as "coming together" or "intertwining." Polyphony could appeal to the imagination, through the construction of images (here, consonances) reflecting order, and to the intellect—*ratio*—through numerical porportion. But its impact on the aural sense was the most perplexing and the most dangerous. The medieval concept of the psyche was of a tripartite mind: "The recollective faculty is placed at the rear [of the head], the speculative power is foremost, and reason exercises its power at the center."[30] Sound infiltrates the first two on its way to the memory, from which it is then often impossible to eradicate. Polyphonic sounds in the memory could be activated—relocated from sense outward through reason to speculation, where they could reflect the harmony of the mind with the external world from which they came. As the temptation grew to make polyphony more complex and sophisticated, so did ideas of order, ideas of music and time.

III

> Music reveals, beyond the manifestations of the senses,
> the inner will that arouses them.
>
> Schopenhauer, *The World as Will and Idea*

It is useful to here reiterate that the invention and performance of early medieval music were oral, and relied "on memory, tradition, improvisation, and non-intellectualism."[31] The foundations of music, then, were not sacred/political—the Church merely appropriated practice—but sacred/ societal, or more accurately, sacred/ communal; the heritage stems from the tribal era,[32] a world of sound and memory but not yet of order. Noise, writes Jacques Attali, is a source of power. "*It is sounds and their arrangements that fashion societies.* With noise is born disorder and its opposite: the world."[33] The evolution of order parallels the development of consciousness, and here we must briefly turn to the affinities between music and rhetoric.

> All human culture was . . . initially rhetorical in the sense that before the introduction of writing all culture was oral. This means not merely that all verbal communication—there are obviously other kinds of communication—was oral, effectively limited to sound, but also that the economy of thought was oral.

So writes Walter Ong in his essay on Rhetoric and the Origins of Consciousness.[34] This economy is a result of the nature of sound. It is not just that sound was an essential means of communication and survival in oral cultures. Sound is unique among the senses in that it is polysemous. Its signals embody multiple meanings, are susceptible to multiple interpretations, because sound, unlike the signals to the other senses, presents itself not in sequence but in simultaneity. Furthermore, since "hearing can not eliminate selectively—there is no aural equivalent of averting one's face or eyes,"[35] of spitting out, of withdrawing touch—sound is inescapable.

Rather than trying to make distinctions, rhetoric unifies, by working "through the imagination, which euphemizes actuality through hyperbole and antithesis."[36] In music, actualities are hyperbolized as well. The perception of sustained and repeated sounds, both macro- and microcosmic, were fashioned into images of order. This order, rhythm, became sacred when one could submit to it in return for protection (from the threat represented in the multiplicity of the sound-world) and security (which became belief and eventually, knowledge). In this way music is linked as semiotics with the rhetoric Ong claims "clearly occupies an intermediary stage between the unconscious and the conscious."[37]

Sachs provocatively suggested that rhythm "played no essential role in the music of ancient and medieval Europe," substantiating this by pointing to the almost total absence of percussion instruments in both Antiquity and the Middle Ages. And Johannes de Grocheo, writing ca. 1300, stated that no monody (sacred or secular) was *ita precise mensurata.*[38] Rhythm was a necessity only in terms of the dance. But dance, being of the flesh, was inferior to song, which, carrying the Word, was at least potentially of the spirit.

Nonetheless, "the major new preoccupation of composers and theorists of music in the twelfth and thirteenth centuries [was] the coordination of time, a newly recognized dimension for musical ordering," writes Treitler. "The regulation of two or more voices in respect of both pitch and time created a new level of complexity. It called for decisions to be made in advance"—decisions now in the hands of the composer—"and communicated, through notation"—now a set of instructions which restricted improvisation and were to become more and more specific—"to performers. The effect of this was a tendency to fix music, both conceptually"—ideas of what music was and what it could be used for—"and notationally—not for canonical reasons"—these were beginning to lose, ever so gradually, their validity—"or initially for aesthetic ones"—these would be noticed later—"but primarily for practical purposes."[39]

But why regulation, and why the tendency to fix? The Timaean universe created by God was one of perfect, perpetual, harmonious, circular motion. If in the medieval mind morality was a process of subservience, of submission, of self-imposition, why the growing need to control the external world of sound? Perhaps it was not to facilitate finding one's place in the Divine Plan, not another allegory of world harmony, but a symptom of the soul in disharmony.

> The major change in the mind of man . . . which distinguishes the Middle Ages from antiquity and which caused the fundamental reconstruction of man's basic concepts and attitudes is centered around the act of redirecting the path of causality.[40]

Redirection began with the birth of Christianity, "God's personal entry into history,"[41] and the consequent concept of linear time. This concept generated the medieval distinction between vertical and horizontal truth, allegory and typology, and originated with Augustine. Augustine presented his discovery of the relation of time to memory in the eleventh chapter of the *Confessions:*

> I am about to repeat a Psalm that I know. Before I begin, my expectation is extended over the whole; but when I have begun, how much soever of it I shall separate off into the past, is extended along my memory; thus the life of this action of mine is divided between my memory as to what I have repeated, and expectation as to what I am about to repeat; but "consideration" is present with me, that through it what was future, may be conveyed over, so as to become past. Which the more it is done again and again, so much the more the expectation being shortened, is the memory enlarged; till the whole expectation be at length exhausted, when that whole action being ended, shall have passed into memory. And this which takes place in the whole Psalm, the same takes place in each several portion of it, and each several syllable; the same holds in that larger action, whereof this Psalm may be a part; the same holds in the whole life of man, whereof all the actions of man are parts; the same holds through the whole age of the sons of men, whereof all the lives of men are parts.[42]

In chapter 12, Augustine distinguishes between sound and music; "a tune is a formed sound." Time is the *sine qua non* of one becoming the other:

> . . . for we do not first in time utter formless sounds without singing, and subsequently adapt or fashion them into the form of a chant, as wood or silver, whereof a chest or vessel is fashioned. For such materials do by time also precede the forms of the things made of them, but in singing it is not so; for when it is sung, its sound is heard; for there is not first a formless sound, which is afterwards formed into a chant. For each sound, so soon as made, passeth away, nor canst thou find ought to recall, and by art to compose. So then the chant is concentrated in its sound.[43]

Memory of events creates the awareness of time. Time in turn is the vehicle of sound and music. For sound to become music, it must do so at the time it exists; it cannot be refashioned. *It must be fashioned entirely within the present, its own presence.* "But the present, should it always be present, and never pass into time past, verily it should not be time, but eternity."[44] Music is thus an intermittent glimpse (hearing, really) of eternity, passing in and out of existence with time. But why is the present not always present?

Here we may turn to Augustine's earlier *De musica libra sex,* to the final book, in comparison with which the first five were "child's play."[45] We return to the realm of *musica speculativa,* of numerical proportion. Augustine posits a level of numbers, and traces them upwards, each level evoking a new layer of consciousness: hearing through the reacting numbers, recognition through the memorial, pronunciation (singing?) through the advancing, delight through the judicial, appraisal through "still others, and in accordance with these more hidden numbers we bring another judgment on this delight, a kind of judgment on the judicial numbers."[46] Then we find a new, Augustinian insight:

> And, if we have been right in our judgment, the very sense of delight could not have been favorable to equal intervals and rejected perturbed ones, unless it itself were imbued with numbers; then, too, the reason laid upon

this delight cannot at all judge of the numbers it has under it, without more powerful numbers.[47]

This, O'Connell believes, implies that reacting numbers—embodying sound—are at the bottom of a cascade of numbers proceeding from God, and that the even deeper implication, therefore, "is that the intelligible is, quite literally, a 'remembered' world, one of which the soul is literally reminded, to which it needs to be recalled."[48]

That the experience of time is a reflection of the soul's fall from grace is an idea that recurs in the *Confessions*. After discussing the memorial-temporal relation and applying it to the whole life of mankind, Augustine adds, "but because Thy loving-kindness is better than all lives, behold, my life is but a distraction."[49]

Plotinus had written that the soul passes from an original, timeless state into motion, and that "time moved with it."[50] Being in time means motion in time. It is a fallen condition; we have been "sewn into the order" of time as a consequence.[51] In the Augustinian meaning, the original sin was tripartite: through 1) curiosity, the soul was seduced into 2) "carnal concupiscence," which, by detouring the soul's attention to the body, results in 3) neglect of the soul's true master, God.[52] Original sin was the result of what Plotinus called the element of "restlessly active nature" contained in the soul;[53] the world of time is the punishment for that sin by prolonging it. The world we perceive through the lower levels of numbers is a product of our morality.[54]

But morality, as the Middle Ages knew, is in use, specificially, in *bene utendo*. The mind could be freed from time by using time. Had human nature remained obedient, it "should have no such connections as are contingent on birth and death."[55] The implication could not be more clear: time and sin are coeternal. Through the use of time to transcend time, music could communicate the very knowing of God. Truth, the Middle Ages also knew, depended on the accuracy of reproduction of an idea.

Notes

[1] de Bruyne, Edgar, *The Esthetics of the Middle Ages*, trans. E. B. Hennessy. New York: Frederick Ungar, 1969. p.44.

[2] Perl, Carl Johann, "Augustine and Music," *Musical Quarterly*, XLI, 4 (October 1955), 507.

[3] Strunk, Oliver, *Source Readings in Music History*. New York: W. W. Norton and Co., 1950. pp. 3-56.

[4] Rowell, Lewis, "Time in the Musical Consciousness of Old High Civilizations—East and West," in *The Study of Time*, III, ed. J. T. Fraser, N. Lawrence and D. Park. New York: Springer-Verlag (1978) 606.

[5] Georgiades, Thrasybulos, *Music and Language*. Cambridge: Cambridge University Press, 1982. p. 4.

[6] de Bruyne, *op. cit*, p. 48.

[7] Kresteff, Assen D., "*Musica Disciplina* and *Musica Sonora*," Journal of Research in Music Education, X, 1 (Spring, 1962), 13.

[8] Boethius, *The Consolation of Philosophy*, trans. S. J. Trester. Cambridge: Cambridge University Press, 1923. 21-25.

[9] Kresteff, p. 18.

[10] Huizinga, J. *The Waning of the Middle Ages*. Garden City: Doubleday and Co., n.d. (originally publ. 1924) p. 267.

[11] *ibid.*, p. 268.

[12] *ibid.*, p. 269.

[13] *ibid.*, p. 267.

[14] Augustine, *Confessions*, trans. E. B. Pusey. New York: Pocket Books, 1951. p. 202.

[15] Huizinga, pp. 267-68.

[16] Sachs, Curt, "Primitive and Medieval Music: A Parallel," *Journal of the American Musicological Society*, XIII (1960), 44.

[17] *ibid.*, p. 46.

[18] Erickson, Carrolly, *The Medieval Vision*. New York: Oxford University Press, 1976. p. 66.

[19] Ibid., p. 43. For another viewpoint on the relations between Church, music, and medieval life, see Huizinga, pp. 250-51.

[20] Hoppin, Richard, *Medieval Music*. New York: W. W. Norton and Co., 1978. p. 186.

[21] Barker, Andrew, ed., *Greek Musical Writings*, v.I. Cambridge: Cambridge University Press, 1984. pp. 175-76. Elsewhere, Barker elaborates Sach's issue of the "sham legalization of lawlessness:" "The *harmoniai* are treated as theoretical abstractions of melodic sequences occurring in actual tunes . . . rather than as scalar structures consciously adopted by the musicians themselves to form a predetermined framework for their melodies." (*ibid.*, p. 281n)

[22] Treitler, Leo, "Homer and Gregory: The Trans-

mission of Epic Poetry and Plainchant," *Musical Quarterly*, LX, 3 (July 1974), 341-42.

[23] Treitler, *ibid.*, p. 342, and "Reading and Singing: on the genesis of occidental music-writing," *Early Music History* 4, ed. Iain Fenlon, Cambridge: Cambridge University Press, 1984, pp. 141-53 and *passim.* Note especially, in the latter article, Treitler's observation that the concept of music as language is a "topos that runs through the medieval theoretical literature as the fundamental principle of musical structure." (p. 146)

[24] ______, "Reading and Singing," p. 141.

[25] *Dictionary of Folklore, Mythology, and Legend* (1972), pp. 825-29, cited in Treitler, "Oral, Written, and Literate Process in the Transmission of Medieval Music," *Speculum,* 56, 3 (1981) 488.

[26] Treitler, "Oral, Written, and Literate Process in the transmission of Medieval Music," *Speculum,* 56, 3 (1981), pp. 489-90.

[27] *musica enchiriadis,* ed. Martin Gerbert in *Scriptores ecclesiastici de musica medii aevi* (St. Blasien, 1784, I, 172), cited in Bukofzer, "Speculative Thinking in Medieval Music," *Speculum,* XVII, 2 (April 1942) 174.

[28] Bukofzer, *ibid.*, p. 174.

[29] Strunk, p. 88. Compare this with the definition proposed by Webern, paraphrasing Goethe: "Music is natural law related to the sense of hearing." (*The Path to the New Music,* Bryn Mawr, 1963, p. 11)

[30] Bernardus Silvestris, *Cosmographia,* trans. W. Wetherbee. New York: Columbia University Press, 1973. p. 123.

[31] Sachs, p. 44.

[32] *ibid.*

[33] Attali, Jacques, *Noise,* trans. B. Massumi. Minneapolis: University of Minnesota Press, 1985. p. 6. On noise as disorder, cf. Kubler, George, *The Shape of Time,* New Haven: Yale University Press, 1962. p. 20. "All substantial signals can be regarded both as transmission and as initial commotions."

[34] Ong, Walter, S. J. *Rhetoric, Romance, and Technology*, Ithaca: Cornell University Press, 1971. p. 2.

[35] Ong, Walter, S. J. *The Presence of the Word,* New Haven: Yale University Press, 1967, p. 130.

[36] Gilbert Durand, *Les Structures anthropologiques de l'imaginaire* (Paris, 1960), cited in Ong, *Rhetoric, Romance, and Technology*, p. 13.

[37] Ong, *ibid.* pp. 11-12.

[38] Sachs, p. 46.

[39] Treitler, "Oral, Written, and Literate Process," pp. 490-91.

[40] Kresteff, p. 20.

[41] Ong, *The Presence of the Word,* p. 11.

[42] Augustine, pp. 236-37.

[43] *ibid.*, pp. 264-65.

[44] *ibid.*, p. 224.

[45] *De Musica,* VI, cited in O'Connell, Robert J., S.J. *Art and the Christian Intelligence in St. Augustine.* Cambridge: Harvard University Press, 1978. p. 66.

[46] *De Musica,* VI, cited in Perl, p. 503.

[47] *ibid.*, p. 504.

[48] O'Connell, pp. 66-68, 70-71.

[49] Augustine, p. 237.

[50] *Ennead,* III, 7, "On Eternity and Time," cited in O'Connell, p. 79.

[51] *De Musica,* VI, 30, cited in O'Connell, p. 75.

[52] *De Musica,* IV, *op. cit.*, p. 74.

[53] *Ennead, op. cit.*

[54] O'Connell, p. 84.

[55] *De Vera Religione,* 88. cited in O'Connell, p. 89.

POPULATION ECOLOGY OF ROCK DOVES IN A SMALL CITY

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Abstract:
We studied population dynamics of rock doves *(Columba livia)* in Stevens Point, Wisconsin from June 1976 through September 1977. A relatively stationary population of about 900 rock doves used 112 roosting sites within the city. Eight communal roosts contained 70% of the population. Rock doves nesting in communal roosts may be more productive than pairs nesting on houses. Annual increment was estimated at 43%, but mortality and dispersal rates were balancing. Rock doves were relatively healthy; the only zoonosis was *Chlamydia,* found in 21% of 103 blood samples. Rock doves were considered a nuisance by 37% of 1,299 households interviewed. The rock dove population should be managed by reducing the number of large roosts and adopting procedures to reduce food sources.

INTRODUCTION

Rock doves (feral pigeons) can be found in almost every urban area in North America, and are controversial in most. Large concentrations can cause health hazards (Scott 1964), noise, aircraft threats (Solman 1974, and economic loss (Murton et al. 1972*a*). By contrast, they are beneficial scavengers, and the only large wild bird readily viewed in downtown areas (Scott 1961). Most efforts to reduce the population size of rock doves have temporary effect until the population recovers through recruitment (Scott 1961, Murton et al. 1972*a*). This study was initiated in response to complaints of nuisance rock doves. It examines recruitment, nesting locations, movement patterns to food and water, and nuisance status of rock doves in a typical midwestern city to identify weak ecological links which might be exploited for population control.

STUDY AREA

The city of Stevens Point in Portage County, central Wisconsin, contains 24,000 people in an area of 29 km^2. Most houses and business establishments within the inner core of the city were built between 1870 and 1930. Architectural designs include Italianate, Victorian, Neoclassical Revival, Prairie, and Southwest Bungalow. Churches are of the Gothic style with domes showing Polish influence. Suitable rock dove roosting and nesting habitat results from the intricate ornamentation, complex roof structure, gables, and long over-hanging eaves of buildings. Such architecture is typical of urban areas in Wisconsin. Railroad cars transporting grain are subject to spillage, and are emptied and washed in Stevens Point, providing rock doves with food. Winters are severe, averaging 74 days/year when the maximum temperature is 0°C or below. Stevens Point averages 122 cm of snowfall/year.

METHODS

From June 1976 through September 1977 daily movements were observed with spotting scope and binoculars from high vantage points. Nesting and roosting-site suitability was identified by the number of rock doves using the site, amount of overhead cover, and nesting success after a season of observation. Productivity of 15 house nest sites and 2 church communal nest sites was compared during summer 1977.

Rock doves were live-trapped with a wood frame drop net triggered by a pull-string, a wood frame top-slotted drop-in trap, and with a fish landing net used in the roosts at night. Doves were banded, and marked with color-coded patagial tags and spray paint on wings to identify individuals and flocks. Population density was identified by 2 types of monthly observations: doves were counted in their roosting areas by night, and at feeding and loafing sites by day. Flock counts were most effective during winter, when rock doves concentrated daily at loafing areas, and few were on nests. Photographs were used to facilitate counts of large flocks. At intervals each month, daily observations of movement patterns to food and water were made from roofs of various buildings within the city, and on ground near roosting, nesting, staging, feeding, watering, and loafing areas. During winter months, local rural pigeon roosts were surveyed with binoculars for marked dispersed urban rock doves. Doves loaf on roofs of silos, barns, and other buildings, especially on clear, cold winter days. Requests were made through the local newspaper for sightings of marked rock doves outside of Stevens Point.

Blood samples and cloacal swabs were collected monthly and analyzed at cooperating laboratories for the following zoonoses and blood parasites: influenza, parainfluenza, Newcastle disease, western equine encephalitis, eastern equine encephalitis, St. Louis equine encephalitis, California encephalitis, chlamydiosis, histoplasmosis, blastomycosis, cryptococcosis, salmonella, *Haemoproteus, Leucocytozoan, Plasmodium.* Blood was obtained through heart puncture with a 22 guage, 3.8-cm needle used with a 5 cc vacutainer. All rock doves were returned alive to the population.

Results

Nesting and Roosting Sites.—Most of the 112 nesting locations found were in the central part of the city where the older houses and buildings are located. Eight large (<30 birds) nest sites accounted for 70% of Stevens Point's rock doves. These large nest sites were higher than 6 m, protected from the weather, and inaccessible to humans and other animals.

Of 970 rock doves, 30% nested on 92 houses. These were older houses with eaves, dormers, roof support brackets, or other structures of a characteristic height, shape, depth, and overhead coverage lacking on newer houses in the city. A count of 502 houses with apparently suitable nesting habitat in the community indicated that 12-15% of available nesting structures were being used. Rock doves roosted mostly under the dormer eaves and on the brackets. Single pairs of rock doves occupied the roost/nest niches of houses. Additional rock doves roosting at the same site usually were the pair's most recent progeny. The mean height from the ground of a house roost was

Table 1. Results of a survey of all Stevens Point households with rock doves where the question, "Do you believe pigeons are a nuisance?" was asked.

Households interviewed ($N = 1299$)	N	%
Nuisance	475	36.6
Not nuisance	750	57.7
Undecided	74	5.7
Total	1299	
Answers from people who had encounters with rock doves on their property.		
Nuisance	59	50.0
Not nuisance	44	37.3
Undecided	15	12.7
Total	118	
Answers from people who did not have encounters.		
Nuisance	416	35.2
Not nuisance	706	59.8
Undecided	59	5.0
Total	1181	

6.5 m. Selection by rock doves of aspect $N=107$) showed no distinct pattern, although they seemed to avoid west, north, and south sides of houses.

A complete house-to-house survey of the central (older) section of Stevens Point, where rock doves occurred, was conducted for locations of pigeon activity and to determine if people considered rock doves a nuisance. Of 1,299 people sampled, 58% thought rock doves were not a nuisance (Table 1).

Production.—We banded, marked, and released 284 rock doves, including 56 juveniles, with patagial markers. We monitored 281 nests (246 nests at 2 churches, 30 nests on 15 houses, 3 nests in trees, 2 nests at a school).

During April-August 1977, 86% ($N=70$) of the house-nesting rock doves nested on the 15 houses studied intensively. House-nesting rock doves usually did not renest (Table 2) or nest at all during a 5-month period from late fall to early spring. Hatching success of 281 nests observed throughout the city was 71%. From 544 eggs laid, 288 rock doves (53%) fledged. During April-August 1977, 70 house-nesting rock doves fledged 37 young, or 53% of their population, compared to 104% for the 2 churches studied (Table 2). The number of young produced was different ($P<0.01$, $x^2=9.47$,

TABLE 2. Productivity of communal nest sites versus house sites in Stevens Point, WI, 1977.

		Communal		
Total	*Houses (N=15)*	*St. Stansilaus Church*	*St. Joseph Church*	*Combined*
N rock doves	70	65	46	111
N Nests[a]	30	54	31	85
N fledged	37	67	48	115
Fledglings/nest	1.23	1.24	1.55	1.35

[a] Includes renests.

TABLE 3. Estimated productivity and annual increment for the Stevens Point, WI, pigeon population, 1977.

Roost site	N *Roosting*[a]	N *nesting*	N *nests*	*Total*[d] *young/year*
St. Stanislaus[b]	100	66	33	134
St. Joseph[b]	75	46	23	93
Shippy Store[b]	100	24	12	49
St. Stephen[b]	50	20	10	41
Fox Theater[b]	100	10	5	20
Dam	50	—	—	—
Old Main[c]	75	30	15	37
Black Bridge[c]	50	30	15	37
Houses[c]	291	210	105	258
Total	891	436	218	669

[a] Average *N* pigeons at roost site.
[b] Communal roost productivity value of 1.35 fledglings/nest and 3 nests/year.
[c] House roost productivity value of 1.23 fledglings/nest and 2 nests/year.
[d] Total young = nests x productivity value (b or c).

$$\text{Annual Increment} = \frac{N_T - N_O}{N_T} = \frac{(891+669)-891}{1560} = 43\%$$

df=2) between the 15 house sites studied and the communal nest sites in the 2 churches, but the number of fledglings/nest was similar between 1 of the churches and the houses (Table 2). On the 15 houses studied intensively, at least 57% of the rock doves were non-breeders (Table 2); on the 92 houses with rock doves, at least 28% of the rock doves were non-breeders (Table 3). In the 2 communal nest sites studied intensively, at least 28% of the rock doves were non-breeders (Table 2); in the 5 communal nest sites, at least 61% of the rock doves were non-breeders (Table 3). Overall, 51% of the rock doves in Stevens Point were non-breeders in 1977 (Table 3).

Although more nests were produced in the 1st nest attempt, nest success reached 71% with the 3rd nest attempt (Table 4), of which 68% were started in June and July. First nest attempts of the year were 81% successful during April through July 1977. No eggs were laid in December and January and no young fledged in February.

The rock dove population was relatively stable, fluctuating between 850 and 1,030 birds from May 1976 to August 1977, or 76-89 rock doves/km² (Table 5). In August 1976, 66% of the population of rock doves (N=910) lived in communal nest sites, 32% on houses, and 2% on other buildings. A population decline in March 1977 followed a very cold winter. A decline in May 1977 resulted from more rock doves (140) than usual being shot by the Stevens Point Police Department in response to complaints; the effect on nesting is unknown.

Mortality and Dispersal.—We estimated an annual increment of 43% for the rock dove population by expanding productivity values obtained from known church and house nest sites to the other nest sites in Stevens Point (Table 3). From January through August 1977, the mortality of 155 rock doves was accounted for. With an estimated production of 670 rock doves, 515 rock doves remained unaccounted for. Although the study period did not cover the last 4 months of 1977, data from the same period in 1976 indicated that little mortality occurred. We found only 8 dead rock doves from September to December 1976. Much of this mortality probably was caused by human-related activities (i.e., shooting, trapping, road-kills). Such mortality was difficult to monitor because some people shoot and trapped rock doves secretly, and road-kills often were picked up immediately by the city sanitation crew. Dispersal, perhaps to rural roosts, may have been high. No marked rock doves were observed during 3 visits to adjacent rural roosts in winter

TABLE 4. Nest attempts of 64 pairs of rock doves at 2 churches and the fate of their 160 nests, Stevens Point, WI, January-September 1977.

	N *nest attempts*					
	1	*2*	*3*	*4*	*5*	*6*
N nests	64	41	28	20	6	1
Nest mortality[a]	15	12	7	8	3	1
N successful[b]	36	28	20	10	2	0
N unsuccessful	28	13	8	10	4	1
% success	56.3	68.3	71.4	50.0	33.3	0

[a] Nest mortality = number of nests abandoned or destroyed before hatching and is part of the unsuccessful nests.
[b] Successful nest = fledged at least 1 young.

TABLE 5. Monthly census of rock doves in Stevens Point, WI.

Time	N
May 1976	850
June 1976	910
July 1976	900
August 1976	910
September 1976	950
October 1976	1000
November 1976	1010
December 1976	1020
January 1977	950
February 1977	950
March 1977	880
April 1977	1030
May 1977	890
June 1977	960
July 1977	975

1976, and no one responded to newspaper articles requesting sightings of marked rock doves outside Stevens Point. However, in 1986, a student reported shooting a banded rock dove in late 1977 at his rural farm about 10 km from Stevens Point.

We found 4 rock doves killed by hawks, 1 by an owl, 10 by car collision, and 4 by shooting. We found 4 adult and 88 juvenile rock doves dead in the 2 church nest sites, August 1976-August 1977, with a high of 14 dead juveniles in September 1976 and March 1977. Of 53 juveniles patagium-marked at the 2 churches from May through August 1977, 43% were recaptured there at the end of August 1977. Others were observed on ledges outside the churches, on nearby houses, and at communal nest sites downtown.

Tests for zoonoses produced positive results only for *Chlamydia,* which occurred in 21% of 103 blood samples examined for it. Of 224 blood smears examined for parasites, 3% contained 7 *Haemoproteus* and 1 suspected *Plasmodium.* These results reflect a low incidence of parasites compared to other studies (Table 6). No other zoonoses were found in the 451 blood samples, 384 cloacal swabs, and 15 fecal samples examined.

Movement to Food and Water.—The Soo Line railroad track area within Stevens Point's city limits was the main feeding area. Most rock doves spent at least part of each day there. After snow melt this source was augmented by seeds and litter picked up in an athletic field and throughout the city, but the tracks were the main food source. Water was obtained from pools on buildings after precipitation and from the Wisconsin River. The Wisconsin River was used more often during summer.

Observations revealed the following daily schedule for rock doves in Stevens Point during summer:

Sunrise to 1 hour after—about ⅓ of the city's rock doves were feeding, courting, and flying in the Soo Line track area. Others were occupied with young and/or eggs or loafed near the roost area.

Rest of morning—the rock doves were back around the roost site or in its general area. They loafed in the sun or picked up food and grit nearby. Noon through afternoon—the birds were back at the Soo Line tracks, but not all at the same time. During this period, small groups (4-25) were constantly leaving and flying into the area; only 150-300 birds could ever be counted at any one time at the railroad tracks. However, during this period most of the city's rock dove population visited the Soo Line track area as the primary food source in the city, as evidenced by color-coded patagial tags and spray-painted wings.

One hour before sunset to sunset—the rock doves were in or near the roosting area, loafing or feeding.

Sunset—all rock doves were roosting.

During winter the schedule changed in that the rock doves arrived at the tracks 3 hours after sunrise and left 3 hours before sunset. They spent proportionally more of

TABLE 6. A comparison of various geographical locations for the incidence of *Haemoproteus columbae* in rock doves.

% infection	N *rock doves Sampled*	*Location*	*Authority*
3.0	224	Stevens Point, WI	This study
58.3	60	Henrico Co., VA	Jochen 1962
82.2	—	Honolulu, HA	Kartman 1949
57.7	—	Parana, Brazil	Giovanni 1946

their time in the track area during winter because it was their only food source and no nesting occurred. Therefore, we saw larger concentrations (500-800) at the tracks during winter. Spring and fall were transitional periods between the 2 schedules.

Discussion

Nesting and Roosting Sites.—Rock dove roosting/nesting sites in Stevens Point were characteristic of those in other urban areas (Potts and Wolmendorf 1960, Scott 1961, Woldow 1972). Feral rock doves are colonial nesters like their ancestors which nest in coastal caves (Gompertz 1957) and roost in groups (Goodwin 1960). Rock doves in Stevens Point used only 12-15% of available house roosts and all available communal sites. Communal sites were crowded. House sites may be marginal habitat for rock doves, perhaps occupied by surplus or subordinate birds from overcrowded communal sites, as Murton et al. (1974) suggested.

We observed no seasonal preference of nesting sites. Rock doves leave sites exposed to cold weather winds (Woldow 1972), and move to locations not facing prevailing winds (Murton et al. 1972*b*). The rock doves of Stevens Point were observed to avoid cold winter winds, seek shade during hot summer days, seek sunlight during cold winter days, and avoid the north and west sides of houses which receive the harsh cold winds of Wisconsin's winters, and the south side which was hot during nesting in summer. Overhanging eaves of dormers and the proximity of other houses apparently provided enough protection from the weather all year on some houses. Rock doves used certain houses as loafing areas during winter days; these houses had poorly insulated, gently sloping roofs. Roofs too steep were difficult to walk on. Poorly insulated roofs radiated heat which reduced snow and perhaps warmed the rock doves.

Population Characteristics.—The relative monthly stability of the rock dove population probably was due to a combination of year-round availability of food and water, relatively few breeders (49%), distributing reproduction over a long time (9 mo.), and probably high dispersal rates. The size of the rock dove population (850-1030) in Stevens Point may be related to the number of communal nest sites within the city, food availability, and low incidence of parasites and disease. Four large sites not intensively studied in the downtown area were used by 300 rock doves, but only an estimated 18% nested in what may have been generally unsuitable nesting habitat with few nest sites. These sites also may have contained many young-of-the-year from other sites; young rock doves marked from the 2 churches were seen at these sites.

Human-related activities probably were the major mortality factors for adult rock doves. Most of the increment of young birds could not be accounted for later, and may have dispersed outside the city or the population pressure may have forced subordinate non-breeding adults to disperse. Because many fledged young-of-the-year were forced from their natural area by established adults, they probably sustained higher mortality than adults from shooting and trapping. Fledging success in Stevens Point compared favorably with that in Maryland (Schein 1954), England (Murton et al. 1972*a*), and New Zealand (Dilks 1975) even though weather extremes are greatest in Stevens Point. Mortality of squabs may result from exposure, disease, and sibling rivalry. Murton and Clarke (1968) stated that the weakened condition of adults in late summer due to moulting, rearing several clutches, and a lack of food supplies caused higher nestling deaths. The cold winters of Stevens Point may eliminate rock doves that are weak or subordinate. Weak birds which are often chronic or subclinical disease carriers may succumb with the added stress of weather. Subordinate rock doves also may be culled from the population by exposure to winter weather.

The 2 church communal nest sites produced more young than the house sites partly because rock doves prefer communal nest sites; more rock doves are available to produce more young there. The apparent difference in the number of birds fledged probably is due to most birds in the churches nesting and many renesting. House nesting birds laid only 1 clutch or did not nest during a 5-month period. Murton et al. (1974) stated that rock doves which could not establish themselves at their natal area were subordinate. Murton et al. (1974) also stated that reproduction was best at the natal area. Displaced rock doves from the Stevens Point communal roosts therefore might not be as successful.

Ready sources of food and water in Stevens Point were available throughout the year only a short distance from the nest sites. Especially important is the availability of food and water at the railroad tracks during winter, when the ground is covered with snow. The food that is eaten at the tracks is supplemented by weed seeds found within the city during spring and summer. Murton et al. (1972*a*) stated that food directly affected the breeding success and size of a population of rock doves in Manchester, England. Ricklefs (1972) stated that the number of clutches is an integral part of the annual fecundity and depends in large part on the length of the season that is suitable for reproduction. Ricklefs (1972) also noted that the long breeding season in rock doves is attributed to their varied and flexible diet.

The results of the rock dove nuisance survey and the complaints which led the city of Stevens Point to invite and support our study suggest that rock doves are a valued wildlife resource, but that the density of 76 rock doves/km^2 is too high. Public opinion must be considered in management objectives. Efforts should be aimed at maintaining an acceptable population size by monitoring and managing on an annual basis. Temporary rock dove control, such as shooting, trapping, drugging, poisoning, repellents, or destruction of nests and eggs, have been tried in other cities with relatively little success (Scott 1961) because they are short term in effect. The public often is offended by many of the temporary control measures (Penn 1965). Some of these are of value when used in conjunction with more permanent measures.

Control efforts should concentrate on nest site elimination and prevention. These methods offer permanent control and have been part of successful rock dove control programs (Potts and Wolmendorf 1960, Scott 1961). In the case of Stevens Point, the dependable source of food at the railroad station was probably the key factor, especially in winter, in maintaining the population of rock doves at 76-89/km^2. The daily practice of washing out grain cars with hot water provided a regular source of food, grit, and water during these critical months. Reduction of the rock dove population probably would occur if the station could reduce the spillage of grain atop grain cars and on the tracks, and if it could wash the cars less often, inside a building, or on top of a single catch basin to which the birds were prevented access.

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IDENTIFICATION OF WISCONSIN CATFISHES (ICTALURIDAE): A KEY BASED ON PECTORAL FIN SPINES

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Abstract

A key to the pectoral fin spines of the freshwater catfish of Wisconsin is provided and these are compared with the spine characters as described from regions adjacent to or near Wisconsin. The key is based upon the size, shape, and orientation of the spines and the bony structures found on them.

INTRODUCTION

Identification of catfish species is not always easy. Conventional means of identification are such features as the number of anal fin rays and the color of chin barbels, which are not always conclusive since there is considerable overlap between species. For example:

Overlap of anal ray counts in the genus *Ictalurus* (Slastenenko 1958, Pflieger 1975, Becker 1983).

species	anal ray count		
	Slastenenko	Pflieger	Becker
Ictalurus melas	16-22	17-21	15-21
Ictalurus nebulosus	19-24	22-23	21-24
Ictalurus natalis	23-28	24-27	24-27

The present study confirms that, by analyzing pectoral fin spines alone, most Wisconsin catfishes can be identified to species.

Since pectoral fin spines are persistent bony structures they are useful in providing the biologist with an important tool for the identification of badly decomposed specimens, skeletal materials, and food habits of fish-eating birds, mammals, and reptiles.

MATERIALS AND METHODS

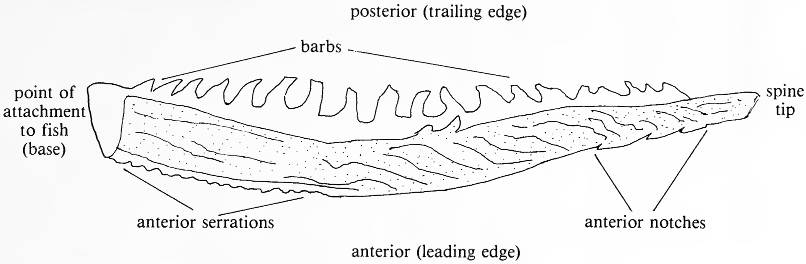
The following key to the spines of the ictalurids of Wisconsin is based upon the observation of spines from 571 *Ictalurus melas,* 102 *Ictalurus natalis,* 83 *Ictalurus nebulosus,* 60 *Ictalurus punctatus,* 4 *Pylodictis olivaris,* 145 *Noturus gyrinus,* 74 *Noturus flavus,* and 44 *Noturus exilis.* Personal collections were made from the Oconomowoc River and from the Wisconsin River, but the principal source of specimens was the Museum of Natural History at the University of Wisconsin in Stevens Point.

In this study the right pectoral spine, while held at right angles to the body was removed flush with the body using a jeweler's saw. The portion of the spine removed included the main shaft and its toothlike projections (barbs). Fin tissue was thoroughly teased from the spine with pins, razor, and forceps using a 20X dissecting scope. Characteristics of the ventral side of the spine were noted. Occasionally bony material on the dorsal side obscures size and shape of some barbs.

The bottom (ventral) side of the spine often shows important distinguishable features more readily than the top (dorsal) side. This is particularly true near the base of bullhead spines where bone on the dorsal side often obscures detail. Hence all drawings of the right pectoral spine which follow are made from the bottom (or ventral) side.

If one were to lay a fish upon its back with the tail pointing away, the spine on the right would be in the same position as the drawings in the key. Drawings of spines indicate typical shape and average adult size.

Terms used appear as follows:



Results

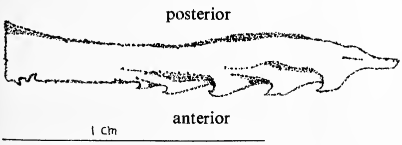
Key to Spines of the Ictaluridae of Wisconsin

1a. Barbs not present on posterior edge . 2

1b. Barbs present on posterior edge 3

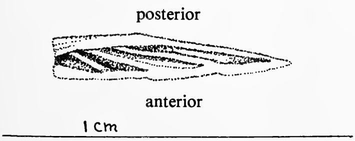
2a. Anterior notches prominent, wide, and deep, extending from tip at least half-way along shaft of spine. Surfaces of the base half of spine smooth and un-furrowed.

STONE CAT
Noturus flavus Rafinesque



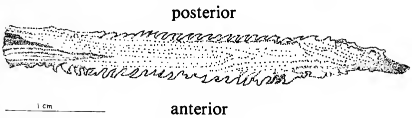
2b. Anterior notches, if present, are delicate and short, and limited to near tip. Both dorsal and ventral surfaces of spine deeply furrowed.

TADPOLE MADTOM
Noturus gyrinus (Mitchell)



3a. Barbs present on both posterior and anterior edges.

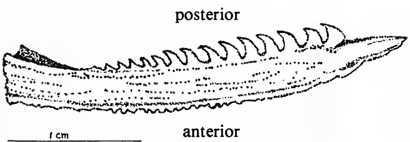
FLATHEAD CATFISH
Pylodictis olivaris (Rafinesque)



3b. Barbs present on posterior edge only 4

4a. Barb heights steadily decreasing from tip of spine to base, showing consistent strong inclination toward base.

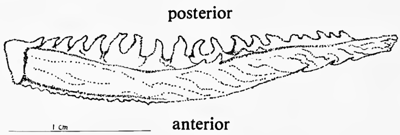
CHANNEL CATFISH
Ictalurus punctatus (Rafinesque)



4b. Barb heights not steadily decreasing from tip of spine to base some upright or showing inclination away from the base 5

5a. Barb heights on posterior edge of spine equal to or greater than one-half the diameter of spine shaft at point of barb attachment.

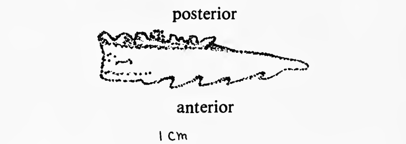
BROWN BULLHEAD
Ictalurus nebulosus (Lesueur)



5b. Barb heights on posterior edge of spine noticeably shorter than one-half the diameter of spine shaft at point of barb attachment 6

6a. Anterior notches extending from tip at least halfway along shaft of spine.

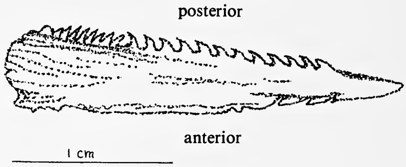
SLENDER MADTOM
Noturus exilis Nelson



6b. Anterior notches, when present, limited to tip of spine 7

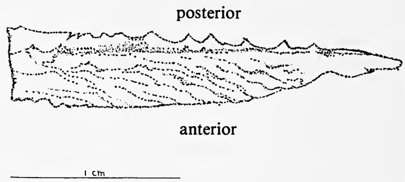
7a. Barbs from tip to mid-spine similar in size, shape, and spacing. Barbs not pyramidal in shape (as an isosceles triangle).

YELLOW BULLHEAD
Ictalurus natalis (Lesueur)



7b. Barbs from tip to mid-spine not similar in size, shape, and spacing. Barbs often pyramidal in shape (as an isosceles triangle).

BLACK BULLHEAD
Ictalurus melas (Rafinesque)



Discussion

Black Bullhead

The pectoral spines of the black bullhead are the most variable of Wisconsin catfish species, showing few consistent characteristics (see ill. under 7b of key). For this species spines with weak barbs have been reported from Illinois (Paloumpis 1963), Missouri (Pflieger 1975), Canada (Scott and Crossman 1973), Ohio (Trautman 1957), and Wisconsin (Becker 1983). Illustrations of black bullhead spines from Missouri, Canada and Ohio are smooth edged, lacking barbs.

According to Trautman, the spines of many young and some small adults may be "somewhat serrated." In Illinois, Forbes and Richardson (1920) reported that weak teeth occur only in adults, and Paloumpis (1963) has observed barbed spines at all ages.

All the Wisconsin black bullheads I examined had barbs on the spines; however Becker (pers. comm.) reported that some individuals "may have only the faintest resemblance to barbs." Although the barbs in the drawing by Becker (1983, p. 145) are less well defined than those I observed, their small size and irregularity allow correct identification to species using the above key.

Other characteristics of bullhead spines that may be useful are the anterior serrations and the anterior notch(es). The anterior edge of the black bullhead spine is generally smooth; however anterior serrations, when present, are small and limited to the part of the spine closest to the base (see ill. under 7b in the key). The anterior notch(es) near the tip of the spine appear(s) in Wisconsin black bullheads although not well defined. This characteristic has also been reported by Paloumpis (1963) from Illinois.

Brown Bullhead

The barbs near the tip of the pectoral spine of the brown bullhead point toward the base, those in the middle are erect, and the barbs near the base point toward the tip (see ill. under 5a of key). Spines from Illinois brown bullheads (Paloumpis 1963) are similarly described.

Brown bullhead spines as illustrated from Missouri (Pflieger 1975), Ohio (Trautman 1957), and Wisconsin (Becker 1983) show shorter barbs than those I observed in my Wisconsin specimens. In Ohio (Trautman 1957) and Canada (Scott and Crossman 1973) brown bullhead spines exhibit several short barbs near the base of the spine.

Yellow Bullhead

The barbs on the spines of the yellow bullhead in Wisconsin tend to be smaller, sharper, and more numerous than those of the two preceding species (see ill. under 7a in key). In Wisconsin specimens a few near the base point toward the tip.

Pectoral spines of yellow bullheads from Illinois (Paloumpis 1963), Canada (Scott and Crossman 1973), and Ohio (Trautman 1957) are similar to those on Wisconsin fish. It is noted however, that in individuals from Canada and Ohio, the barbs at the base of the pectoral spine were shown inclining toward the base instead of toward the tip. Apparently there is plasticity in the morphology of yellow bullhead pectoral spines as observed from different parts of its range. Despite this, such fish would key out correctly with the instrument provided above.

Anterior notches and serrations in the spine of the yellow bullhead are common as they are in Illinois (Paloumpis 1963) but their taxonomic use still needs determination.

Channel Catfish

Barbs on the pectoral spine of Wisconsin channel catfish incline toward the base with barb heights decreasing from tip to base (see ill. under 4a in key). This characteristic was diagrammed in the key by Paloumpis (1963).

In Canada (Scott and Crossman 1973) barbs were found to point in different directions on different parts of the spine.

Flathead Catfish

Barbs on the pectoral spine of Wisconsin flathead catfish are found along the anterior edge of the spine (anterior barbs pointing toward the base of the spine) and along its posterior edge (posterior barbs pointing toward the tip (see ill. under 3a of the key).

The barbs on the spine of a 24-year-old specimen I examined were much reduced, appearing as rounded nubs. Barbs on both anterior and posterior edges may be imbedded in the soft tissue of the fin beyond the bony spine.

Stonecat

The characteristic pectoral spine of the Wisconsin stonecat is illustrated under 2a in the key. The anterior notches are sharp-pointed and inclined toward the base. They are—as Taylor (1969) describes—"recurved hooks." In Wisconsin the posterior edge of the pectoral spine is smooth but Taylor finds it "roughened or sometimes with a few serrae behind."

Illustrations of pectoral spines of stonecats from Canada (Scott and Crossman 1973) and Michigan (Taylor 1969) are similar to Wisconsin specimens and can readily be identified to species with the above key.

Tadpole Madtom

The pectoral spine of the tadpole madtom is short, deeply furrowed on both dorsal and ventral surfaces, lacks barbs, and the anterior notches, if present, are delicate and short (see ill. under 2b in key). Descriptions of tadpole madtom spines from Ohio (Trautman 1957) and Canada (Scott and Crossman 1973) agree with my observations. Illustrations by Pflieger (1975) and Taylor (1969) of pectoral spines from Missouri specimens agree with my observtions and can easily be identified to species with the above key.

Slender Madtom

The barbs on the pectoral spine of the slender madtom in Wisconsin are generally columnar, blunt-tipped, and occasionally with flat tops having small projections (see ill. under 6a in key). The barbs are generally perpendicular to the shaft of the spine, although some inclination of barbs is not unusual. Often barbs close to the tip lean toward the tip. Taylor (1969) also found barbs "usually straight, but sometimes bent outward or inward."

The distinct anterior notches or "retrorse hooks" (Taylor 1969) extend from the tip at least halfway toward the base of the spine.

Acknowledgments

I wish to thank Dr. George C. Becker for critical reading of the manuscript and for his helpful suggestions.

Also, Sharon A. Paruch is to be thanked for her work on the drawings.

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SOME MODERN IDEAS IN ANCIENT INDIA

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Although the East is often referred to as an ancient civilization and India recognized as having had a great past, little is generally known about India's contribution to the world. Some Western writers occasionally turn lyrical when they speak of India's heritage and pour encomium about her past,[1] but there is often a noticeable reluctance among most Western writers to put India before other countries in certain matters where she has clearly excelled. It is not uncommon for a Western Indologist to be excited on first discovering India's greatness in some area and then cool off on second thought. An excellent example is Max Müller, who at first was excited but then became critical.[2] Ancient Indian achievements were both great and varied, and while it is impossible to go into a full discussion of them in this essay, an attempt is made here to recount and explain some of the modern ideas which existed in ancient India.[3]

First and foremost, perhaps, it should be noted that the word *Ārya* comes from Sanskrit, the ancient classical language of India, and etymologically means "to till," while its literal meaning is "noble." The word abounds everywhere in India's ancient writings. According to Western scholars, the Aryans came to India and settled by about 2,000 B.C. They developed the art of agriculture and were the first in the world to grow rice.[4] They domesticated the cow and got from it milk, butter, and ghee.[5] As civilization advanced, their predatorial habits disappeared (though it has been argued that they were never meat-eaters), and they became vegetarians. They are supposed to have drunk *soma*[6] (see Aldous Huxley's *The Brave New World* for a reference to this drink) and much later developed *panchāmrita,* a drink consisting of five ingredients, used even today on festive and religious days, probably a forerunner of the modern punch.[7] The swastika sign originated in ancient India (and is still used on religious and other important days), though the symbol is reversed in the West. The word *swastika* is itself a Sanskrit word and means "the religiously good or auspicious."

One of the most fascinating things our ancestors imagined is space travel. Not only do we have in the first epic, the *Rāmāyaṇa,* an aerial car called Pushpaka that travels from city to city, from country to country, and from planet to planet but we have descriptions of inter-planetary battles. What is more strange, the plane is an automatic, pilotless one. Elsewhere there is an account of crafts used to travel on water, on land, and in air—all in one craft—with some specifications.[8] In the same epic we have flights by Hanuman and also building of bridges across bays—for example, from India to the island of Ceylon.

This epic abounds in the description of the strange and the fantastic. There are, here, weapons of war and destruction not imagined elsewhere till modern times. There are descriptions of weapons, counter-weapons, counter-counter weapons, and counter-counter-counter weapons, and so on. There is, for example, the fire weapon (Āgnyeyāstra), which the hero of one army might release so as to burn down all that is on the other side of the battle field, but before fire envelopes the whole place (compare napalm or cluster bombs), the opponent releases the water weapon (Vāruṇāstra) putting out the fire while at the same time trying to flood the other side of the battlefield. But the hero quickly releases the

Wind weapon (Vāyuvyāstra), which will disperse the water, and so on. There are even terrible world-destruction weapons and missiles like the Aindrāstra, Pāshupatāstra, Vaishṇavāstra, and finally the ultimate weapon, which can destroy the whole world, Brahmāstra. The last one is unstoppable except by the one who releases and knows how to retrieve it before it hits the target. The knowledge of these weapons is restricted to the few who have been taught by a holy preceptor and who have earned by merit their secret and use. There is even in this epic an instance of something like a chemical weapon (sammōhanāstra),which makes the victim lie helplessly foaming at his mouth. As though this were not enough, we have one instance in which the hero, Rāma, uses a straw to convert its atom into an atomic weapon to destroy a demon attacking Sitā, the heroine.

There are strange beings, animals, and birds, too, in this epic, which we come across in the volume entitled the Forest Volume (Araṇya Parva)—mis-shaped animals, animals with huge bodies but extended limbs with which to scoop up their prey for food, birds far bigger than the condor (Jathāyu), and later a demon looking like a hill (Kumbhakarna). The *Rāmāyaṇa* also tells of the Kingdom of the Apes with descriptions of very advanced skills, organization, and knowledge of sophisticated weapons, including some battles and skirmishes. There are many, many noble thoughts, but one of the thoughts that a successful politician of the present day might remember is what Rama the hero is told: *Avasthā pūjyate Rāma, sharīram na pūjyate*—it is the office one holds that is worshipped, not his person. The *Rāmāyaṇa* also affirms a fantastic belief that life sleeps in matter, breathes through plants, speaks through animals, and is completely conscious in man. The story of Ahalyā, who becomes a stone and rises from it again, is astonishing in its foreshadowing of the modern researchers' finding life in the deep sea, frozen antarctic, and hard rocks.

In the *Bhāgavatha* the concept of cities hanging in outer space appears. The story of Tripurāsura (the Three-City Demon), who owns the city is a terrible story of a demon who inflicts punishment on those whom he does not like by descending with his entire city and alighting on an earthly city! The idea that a man in outer space is simply suspended is best illustrated by the story of Trishanku, who tries to ascend to heaven bodily and is rejected at heaven's gate but is stopped again by the sage Vishwāmithra with the result that the King Trishanku simply is suspended in space! The famous Ten Incarnation stories of Vishṇu or the Dashāvatāra stories are a remarkable set of stories which affirm a variety of beliefs. These incarnations of Vishṇu, the Protector, are believed to have happened in an order which is fascinating for certain implications. Vishṇu is supposed to have come down to earth at the request of the human belings, age after age, to destroy evil and to uphold righteousness in the following order: the Great Fish; the Great Tortoise; the Great Boar; the Great Half-Man and Half-Lion; the Dwarf Man; Rāma with an Axe; Rāma, the Great Archer; Krishṇa, the Diplomat; the Compassionate Buddha; and finally Kalki, although the very orthodox do not accept the ninth one. Biological evolution is clearly and simply illustrated by these incarnations. Social evolution is illustrated by the gradual advance of weapons of war and destruction culminating in the most sophisticated ones mentioned earlier, which are then followed by diplomacy as a means of settling disputes and compassion as the ultimate salvation of mankind. The stories, moreover, affirm a cardinal principle of Hinduism that God is realized by each being at its own level and that God appears to different people in different ways in different ages and speaks in different tongues. In the story of Rāma with an Axe (Parashurāma), there is the affirmation of yet another idea—that it is the father who is the true parent and who passes on the heritage. For, when his father, who suspects his wife of infidelity, tells the son to kill his mother, the son hesitates to carry out the behest of the father but finally resolves his dilemma and decides that it is the father who is the true parent. The story of Balarāma, the older brother of Krishṇa, illustrates yet another modern idea. When Kamsa, the demon, tries to kill all babies because of the prophecy in heaven that a certain baby will kill him and become the king (reminiscent of Herod-Jesus story), the embryo in the womb of Devaki is transferred to another woman's womb and Krishṇa's older brother is saved. Later on, of course, Krishṇa is born, taken to a cowherd's house and is brought up there, and he finally kills Kamsa. The story of embryonic transfer dating back some 3,000 and more years is astounding. The same work contains the parallel of the story of Noah's Ark—with one difference. In the Indian story it is not pairs of actual animals that are put in the ark but the seeds of pairs, something that can be more realistically accommodated in an ark.

In the second epic, the *Mahābhārata* (the longest ever to be composed by the human mind—it has about 100,000 verses of 32 syllables each, and the epic is in 18 volumes), we have even more modern ideas. For example, the story of Abhimanyu's learning the peculiar war strategy of Padmavyūha (of organizing a battle army) when it was being described by Krishṇa to his sister, Subhadra, in whose womb the unborn Abhimanyu is still resting, contains an extraordinary idea of teaching a fetus and attests to an old Indian belief that one's education begins in the womb and ends in the tomb. Again, the birth of the Pāndavās, the heroes of the epic, by means of the power of the holy spirits of gods invoked by Kunthi, (and her earlier pregnancy while yet a virgin without human intercourse) clearly foreshadows the story of Christ's birth. The way in which the 100 children are born to Gandhari (the idea of humans coming out of eggs—not believed in by the moderns till probably around the beginning of the century—and of one splitting up into 100) is certainly an astonishing idea, however rudimentary it may be. The *Mahābhārata* also contains a highly developed code of warfare and of treating enemies, including those who surrender. Descriptions of fantastic war weapons repeat themselves in this epic. There are also interesting descriptions of gambling and wrestling matches—when we are back about 3,000 years in time. Karate, it must be remembered, originated in India.[9]

Scattered in a number of places are other fascinating ideas. Constantly we come across the concept of *Divya drishti,* or literally *divine sight.* What this means is that sages and others who are advanced beings can tune their minds and know what is happening, has happened, or will happen—so long as the frequency of their mind is in tune with the thing about which they want to know.

Diamonds, cotton, rice, and peacocks came originally from India. In fact, the Golconda mines of the southern part of India were the mines from which the world received all its diamonds in ancient times.[10] In the words of Basham, "India has conferred many practical blessings on the world at large; notably rice, cotton, the sugar cane, many spices, the domestic fowl, the game of chess (p. 208), and, most important of all, the decimal system of numeral notation, the invention of an unknown Indian mathematician early in the Christian era (p. 495f)."[11] It was India and not the Arabs who invented the so-called Arabic numerals. The myth of Arabic invention has gone on too long. There is incontrovertible evidence to prove that India contributed these numerals and the concept of zero to the world. Basham pointedly mentions this fact:

> The earliest inscription recording the date by a system of nine digits and a zero, with place notation for the tens and hundreds, comes from Gujarat, and is dated A.D. 595. Soon after this however, the new system had been heard of in Syria (p. vi), and was being used as far afield as Indo-China. Evidently the system

was in use among mathematicians some centuries before it was employed in inscriptions, the scribes of which tended to be conservative in their system of recording dates; in modern Europe the cumbrous Roman system is still sometimes used for the same purpose. The name of the mathematician who devised the simplified system of writing numerals is unknown, but the earliest surviving mathematical texts—the anonymous "Bakshali Manuscript," which is a copy of the text of the 4th century A.D., and the terse *Āryabhatīya* of Āryabhata, written in A.D. 499—presuppose it.

For long it was thought that the decimal system of numerals was invented by the Arabs, but this is certainly not the case. The Arabs themselves called mathematics "the Indian (Art)" (*hindisat*), and there is now no doubt that the decimal notation, with other mathematical lore, was learnt by the Muslim world either through merchants trading with the west coast of India, or through the Arabs who conquered Sind in A.D. 712.

The debt of the Western world to India in this respect cannot be overestimated. Most of the great discoveries and inventions of which Europe is so proud would have been impossible without a developed system of mathematics, and this in turn would have been impossible if Europe had been shackled by the unwieldy system of Roman numerals. The unknown man who devised the new system was from the world's point of view, after the Buddha, the most important son of India. His achievement, though easily taken for granted, was the work of an analytical mind of the first order, and he deserves much more honour than he has so far received.[12]

There is a question in the history of mathematics asked about India: "When the whole world was groping in darkness, what did India contribute?" The answer is, "Nothing." This Nothing has been the most important thing in the development of mathematics. Again, Basham says,

"For π Āryabhata gave the usual modern approximate value of 3.1416, expressed in the form of a fraction 62832/20000. This value of π, much more accurate than that of the Greeks, was improved to nine places of decimals by later Indian mathematicians. . . . He [Bhāskara] also established mathematically what had been recognized in Indian theology at least a millenium earlier, that infinity, however divided, remains infinite, represented by the equation $\frac{\infty}{x} = \infty$."[13]

He also adds,

"Despite their inaccurate knowledge of physiology, which was by no means inferior to that of most ancient peoples, India evolved a developed empirical surgery. The caesarian was known, bone-setting reached a high degree of skill, and plastic surgery was developed far beyond anything known elsewhere at the time. Ancient Indian surgeons were expert at the repair of noses, ears, and lips, lost or injured in battle or by judicial mutiliation."[14]

The Oxford scholar MacDonell puts it even more accurately: "In modern times European surgery has borrowed the operation of rhinoplasty, or the surgical formation of artificial noses, from India, where Englishmen became acquainted with the art in the eighteenth century."[15] As for another aspect of medicine, MacDonell holds, "The *Atharvaveda* and the *Sátapatha Brāhmaṇa* contain an exact enumeration of the bones of the human skeleton."[16] Again, the same scholar notes, "One of the Brāhamaṇas [*sic*] observes that the sun does not really rise or set, but produces day and night on the earth by revolving."[17] A little later he adds that Aryabhata "maintained the daily rotation of the earth round its axis, explaining the daily rotation of the celestial sphere as only apparent."[18]

A number of ideas connected with language and literature arose in ancient India. The oldest grammatical text dealing especially with phonetics goes back to the times even before the famous text of Panini (4th-5th century B.C.), who by all accounts, is the most celebrated grammarian that has ever lived. His *Ashtādhyāyee* records a work which has never been equalled till recent times. Says John Lyons, "The Indian grammatical tradition is not only independent of the Greco-Roman but also earlier, more diverse in its manifestations and in some respects superior in its achievements."[19] He adds, "Pāṇini's grammar of Sanskrit has frequently been described from the point of view of its exhaustivness . . . its internal consistency and its economy of statement, as far superior to any grammar of any language yet written."[20] Indians were also the first to produce indexes or *Anukramaṇīs*[21] since they had to do so for the Rgveda. The first systematically arranged dictionary, the *Amarakosha,* was produced by Indians; it is unique in its arrangement of nouns, putting together all synonyms, in the form of verse stanzas, which students learn by heart as they would learn poetry. The *Panchatantra,* a seminal influence on stories of many countries of the world of ancient times, is indeed a remarkable book. Its framing device, or the frame story device, has been used subsequently by a large number of writers including Chaucer in his *Canterbury Tales.*[22] It influenced *Arabian Nights* stories, and MacDonell says, quoting another source, "The story of the migration of Indian fairy tales from East to West is more wonderful and instructive than many of those fairy tales themselves."[23]

About 4,000 years ago even as today, Indians thought of ten directions—the eight common ones plus up and down. We read about the ten directions in the Rgveda, and in the *Rāmāyaṇa,* the King is called Dasharatha, one whose chariot can go unchallenged in any of the ten directions. Similarly, in ancient times, as today, India had thought of five elements constituting the universe as well as the human body, these being fire, earth, water, air, and space. Without space, the fifth element, our bodies would simply be one single block. Again, there is a curious question asked in one of ancient scriptures with a curious answer: "What is this universe? From what does it arise? Into what does it go?" "And the answer is: In freedom it rises, in freedom it rests, and into freedom it melts away."[24] One of the weapons used by Vishṇu and Krishṇa is called Chakra (wheel). When it is released, it goes and kills the enemy and comes back—a better version of the Australian boomerang!

Indians have had their own way of computing time and their own calendar. They also thought that time was differently measured in different parts of the universe. The Indian concept of time even today as in ancient India is a circular one—not a linear concept. They had imagined then, and imagine now, that Brahman, the Creator goes to sleep for eight billion years and then wakes up again. In one of his television lectures Carl Sagan, the American scientist, has pointed out how this computation of eight billion years is very close to the scientific calculation of the contraction of the universe! One of the ancient philosophers, Patanjali, is very modern and anticipates modern science when he says, without postulating a creation, in his *Yogasāstra* that life comes into being when matter and life-force come together. The use of a rosary, washing of the feet of elders on religious occasions, putting the sacred ash on one's forehead (especially among certain sub-groups of Hindus), and praying with folded hands (a form of greeting—in contradistinction to shaking hands in the West) have all existed for more than 3,000 years in India and can be easily documented.

In the composition of secular literature also India was far advanced in ancient times. India's greatest, and not the first, dramatist, Kalidasa, who has been much extolled by English, German, and French writers lived in the 5th century A.D.—eleven centuries before Shakespeare. His dramas are complete with plots containing a king, queen, and court jester and all, and what is more, has a prologue, acts, scenes and epilogue (Shakespeare, it must be recalled, did not divide his plays into scenes). India had drama theaters built to exact specifications.[25] In secular literature ancient India was one of the earliest civilizations to produce romances, which are only one step from what is called novels today. Dandin's *Dashkumāracharita* (6th century A.D.), Bana's *Kādambarī* (7th century A.D.), and Subandhu's *Vāsavadatta* (7th century A.D.) are great works of fiction. Horrwitz says, "Bâna has written the best Sanskrit novel."[26] Today, the word *kādambari* is used in three Indian languages (Kannada, Telugu, and Marathi) to mean "a novel." However, modern novels with all their attention to individuals and with overwrought emphasis on individuals' feelings and thoughts and the central importance of man in the world could not have been produced by ancient Indians, who regarded man as merely a speck in a vast universe except for his soul power. Only when the influence of the West, with its Judeo-Christian tradition and its belief in man as the center of the universe, reached India did India produce modern novels.[27]

One area in which ancient Indian custom and modern Western practice are virtually identical is in the area of teaching. Unlike the modern Indian practice of professors' lecturing to passive students, ancient India chose to teach on an individual basis (each student chose a teacher and the teacher would have to accept him) and by means of question-answer method. The earliest examples of this practice are to be found in the Upanishads, in which stories containing some of the highest truths of India are found to be taught in a dialogue fashion. The *Panchatantra* illustrates the use of circular thinking necessitated by the student's constant questions with the result that even before one story is finished another must begin and so on. Finally, ancient India had a passion for analysis. Indians analyzed and analyzed, and categorized and categorized. Till recently, Indian children in grade school used to learn by heart categories of various things—those that exist in two's, in three's, in four's and so on. This analysis and categorization was applied even to a passionate subject like love, of which Vātsyāyana's *Kāmasūtra* (The Hindu Art of Love) is a redoubtable example. These are some of the modern ideas of ancient India.

Notes

[1] See, for example, the respected American Scholar Arthur W. Ryder's Introduction to his translations of Kalidasa's selected writings, *Shakuntala and Other Writings* (New York: Dutton 1959). The book also carries the German poet Goethe's exaltation of Kalidasa's *Shakuntalam*. Subsequently, he modelled his *Faust* using a Prologue in the manner of Kalidasa. See also Mark Twain [Samuel Langhorne Clemens], *Following the Equator,* in *The Complete works of Mark Twain,* American Artists' ed., 24 Vols (New York: Harper, 1925) 2:16-17, for a frank and mixed reaction.

[2] When he gave his first lectures at Cambridge University, Max Müller was exultant and called the Vedas "the first words the Aryan man spoke" and later turned partly critical. Perhaps the following words from Max Müller give a flavour of is natural and spontaneous initial reaction to the discovery of India's greatness—a reaction uninhibited by other considerations. "If I were to look over the whole world to find out the country most richly endowed with all the wealth, power, and beauty that nature can bestow—in some parts a very paradise on earth—I should point to India. If I were asked under what sky the human mind has most fully developed some of its choicest gifts, has most deeply pondered on the greatest problems of life, and has found solutions of some of them which well deserve the attention even of those who have studied Plato and Kant—I should point to India. . . ." Max Müller, *India: What Can It Teach Us?* Ed. K. A. Nīlakantha Sastry 2nd ed. (Delhi, India: Munshi Ram Manohar Lal, 1961) 6.

[3] The term *ancient India* is used in this essay with the commonly accepted meaning of referring to the period from about 1,500 B.C. or 2,000 B.C. till about the 7th century A.D.

[4] See A. A. MacDonell, *India's Past: A Survey of her Literatures, Religions, Languages, and Antiquities.* Varanasi, India: Motilal Banarasidass, 1956, p. 7. Originally published by Oxford University Press.

[5] Ghee is melted butter oil, as it is called in America. In a hot country at a time when refrigeration was unknown, how astute it was of Indians some 4,000 years ago to come up with an idea to preserve butter! Even today it is the same procedure followed by all in India.

[6] Soma was a mildly intoxicating drink but sura was the forbidden one. For an interesting study of the soma plant, see R. Gordon Wasson *Soma: Divine Mushroom of Immortality* (n.p.: Harcourt, n.d.) Printed in Italy.

[7] E. Horrowitz says, "*Punch* is an Indian beverage consisting of 'five' ingredients." See *A Short History of Indian Literature* (London: T. Fisher Unwin, 1907) 140, f.n.

[8] See *The Hindu,* a very highly respected and overly cautious newspaper of India. "Aeronautics in the Vedic Age," Sunday 27 May 1973, the editorial page.

[9] Karate originated in India, but some writers merely recognize its strong influence on its development. See *The Oxford Companion to World Sports and Games,* ed. John Arlott (London: Oxford UP, 1975) 562.

[10] G. F. Herbert Smith, *Gem-Stones and Their Distinctive Characters,* (London: Methuen, 1912) 137, where he says, "The whole of the diamonds known in ancient times were obtained from the so-called Golconda mines in India."

[11] A. L. Basham, *The Wonder That Was India: A Survey of the Culture of the Indian Sub-continent Before the Coming of the Muslims,* (New York: Grove Press, 1959) 485.

[12] Basham 495-496.

[13] Basham 496. Ancient Indians had a creative mathematical imagination, and they imagined vast numbers of great magnitude. Jawaharlal Nehru gives some interesting facts about this amazing conception of stupendous numbers by Indians. Says he, "The time and number sense of the ancient Indians was extraordinary. The Greeks, Romans, Persians, and Arabs had apparently no terminology for denominations above the thousand or at most the myriad ($10^4 = 10{,}000$). In India there were eighteen specific denominations (10^{18}), and there are even longer lists. In the story of Buddha's early education he is reported to have named denominations up to 10^{50}.

At the other end of the scale there was a minute division of time of which the smallest unit was approximately one-seventh of a second, and the smallest lineal measure is given as something which approximates to 1.3×7^{-10} inches. . . . To them [Indians] the vast periods of modern geology or the astronomical distances of the stars would not have come as a surprise." *The Discovery of India* (London: Meridian Books, 1951) 97-98.

[14] Basham 499-500.

[15] MacDonell 185.

[16] MacDonell 180.

[17] MacDonell 186. See also Nehru, *The Discovery,* 76, where he says, "There is an odd and interesting passage in one of the Upanishads (the Chhandogya): 'The sun never sets nor rises. When people think to themselves the sun is setting he only changes about after reaching the end of the day, and makes night below and day to what is on the other side. Then when people think he rises in the morning, he only shifts himself about after reaching the end of the night, and makes day below and night to what is on the other side. In fact he never does set at all.'".

[18] MacDonell 190.

[19] John Lyons, *Introduction to Theoretical Lingustics* (Cambridge, England: Cambridge UP, 1971) 19.

[20] Lyons 20.

[21] MacDonell 19.

[22] See W. F. Bryan and Germaine Dempster, eds., *Sources and Analogues of Chaucer's Canterbury Tales* (New York: The Humanitties Press, 1958) 6.

[23] MacDonell 126.

[24] Nehru 74-75.

[25] A. Berriedale Keith, *The Sanskrit Drama: Its Origin, Development, Theory, and Practice* (London: Oxford UP, 1970) 358-360.

[26] Horrwitz 137.

[27] It is the theory of this author that the form of literature called novel today did not develop in India not because Indians were preoccupied with the fantastic as some have thought but because of their modesty about themselves as human beings and their correct understanding of their importance and place in the universe. They did not make man the supreme creation, God's favourite, and centre of the universe. Such a mind cannot produce a novel, where sometimes the most trivial thoughts of a character are delineated at length. Modern novels give paramount importance to the individual in a universe where the planet on which an individual lives is itself of diminutive importance.

ALLUSIONS TO THE *AENEID* IN *PARADISE LOST*, BOOKS XI AND XII

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Of all of Milton's works, the last two books of *Paradise Lost* are among those most roundly condemned. C. S. Lewis describes them as a "grave structural flaw." According to Lewis, Milton "makes his last two books into a brief outline of sacred history from the Fall to the Last Day. Such an untransmuted lump of futurity, coming in a position so momentous for the structural effect of the whole work, is inartistic. And what makes it worse is that the actual writing in this passage is curiously bad . . . Again and again, as we read his account of Abraham or of the Exodus or of the Passion, we find ourselves saying, as Johnson said of the ballad, 'the story cannot possibly be told in a manner that shall make less impression on the mind . . .' If we stick to what we know we must be content to say that Milton's talent temporarily failed him . . . Perhaps Milton was in ill health. Perhaps being old, he yielded to a natural, though disastrous, impatience to get the work finished" (129-130). This is not an isolated opinion. Kenneth Muir (143) and E. M. W. Tillyard (216, 246) both found the final books of *Paradise Lost* to be inferior artistically to the rest of the poem. And Samuel Johnson was, I suspect, responding especially to the last two books when he said that, while *Paradise Lost* is widely acknowledged to be a great work, no one, coming to the end of it, has ever wished it to be longer (108).

My secondary purpose this afternoon is to demonstrate, at least in one respect, the care with which these books were fashioned, that respect being the use of epic allusions. My primary purpose, and the one that interests me more, is to argue that, to the first readers of *Paradise Lost*, the *Aeneid* was a guide, and that in Books 11 and 12 of *Paradise Lost*, Milton uses allusions to the *Aeneid* to define the meaning and the peculiar merit of his own epic.

As any annotated edition of *Paradise Lost* makes clear, the poem is replete with allusions to epics, not only to Vergil and Homer, but also to the later Italian epics of Dante, Ariosto, and Tasso. Constant allusion to other epics is part of the genre. The *Aeneid* is filled with lines from Homer and from Ennius and Statius, Vergil's predecessors in Latin epic. Such allusions necessarily invite comparison; Vergil is reputed to have said that "it is easier to steal the club from Hercules than to take a line from Homer" (Harding, 20). The point of such a risk is to claim equality with, if not superiority to, the works alluded to. The method is apparent in the opening lines of *Paradise Lost*, where Milton claims to pursue "things unattempted yet in prose or rhyme" (1.16). Here Milton paraphrases the opening of Ariosto's *Orlando Furioso:* "At the same time I shall say of Orlando something never said before in prose or rhyme: that through love he became frenzied and insane and not that man who earlier was judged so wise." Whatever we think of the novelty Ariosto claims for his subject, the obvious disparity between the subject of *Paradise Lost* and *Orlando Furioso*, revealed by this allusion, concisely implies the superiority of Milton's epic.

For many of Milton's readers, "epic" meant the *Aeneid*. According to Davis P. Harding, Vergil's "major works—the *Eclogues*, the *Georgics*, and the *Aeneid*—form what might be called the hard core of the Renaissance grammarschool curriculum.

Of all the school authors, only Cicero was studied with a comparable intensity. It is probably not too much to say that Renaissance schoolboys practically knew Virgil by heart" (7). The first allusion to the *Aeneid* in Book XI has the same purpose as the opening allusion to *Orlando Furioso*. The subject of the comparison is the nature of deity. When Adam and Eve pray for forgiveness,

> . . . To heaven their prayers
> Flew up, nor missed the way, by envious winds
> Blown vagabond or frustrate . . . (11.14-16)

The description here echoes Apollo's response to Arruns' prayer in Book II of the *Aeneid:*

> Phoebus had heard, and in his heart he answered
> Half of that prayer; the other half he scattered
> To the swift winds. He granted this: that Arruns
> Should strike Camilla down with sudden death;
> But did not grant him safe return to his
> Illustrious homeland. This last request
> The tempests carried to the south winds.
> (11.794-98)

The contrast between the two prayers is sharp. Adam and Eve pray to God for pardon, and receive it. Arruns prays that he might slay Camilla in battle, and that he might return home safe. Apollo's response is that both Camilla and Arruns die.

Just as obvious a claim to a superior deity is Milton's use of augury in Book 11. After Eve remarks to Adam that, even though they are fallen, they might manage quite nicely in the garden of Paradise, Adam notices that the garden is changing:

> Nigh in her sight
> The bird of Jove, stooped from his airy tow'r,
> Two birds of gayest plume before him drove.
> (11.184-86)

In the *Aeneid,* the fate of swans pursued by an eagle twice influences the course of events. In Book 2, Venus uses the regrouping of a scattered flock to persuade Aeneas that his fleet, scattered by storm, has gathered safely at Carthage, and that he can find safety there also (2.393-401). In Book 12, a flock of swans attacks an eagle, forcing it to drop its prey. Juturna uses this event to persuade the Italians to break the truce and attack Aeneas (244-265). Both Venus and Juturna are divine, but their auguries are misleading and disastrous for their human audience. Juturna's counsel leads to the defeat of the Italians and the death of her brother, Turnus. Venus's counsel leads Aeneas to Carthage, where he falls in love with the queen, Dido, abandons his mission of founding Rome, is rebuked by Jupiter and so deserts Dido, who kills herself. Adam, without divine help, draws the correct conclusion, that their present situation is not secure; if the sign is misleading, it is misleading only in that it portends a worse fate for Adam and Eve than in fact occurs. Through prayer and augury, then, Milton reminds us that the classical gods, in contrast to the Christian God, are capricious, self-serving, and deceptive.

Milton does not always use the classical gods merely as obvious foils. At the beginning of Adam's vision, the archangel Michael is twice associated with Venus, and this association helps us to understand his mission. The form in which Michael appears is "solemn and sublime" (11.236):

> over his lucid Arms
> A military Vest of purple flow'd
> . . . .
> His starry Helm unbuckl'd show'd him prime
> In Manhood where Youth ended; by his side
> As in a glistering *Zodiac* hung the Sword,
> Satan's dire dread, and in his hand the Spear.
> (11. 240-41, 245-48)

Despite this militaristic and stern guise, the first allusion associates Michael with a resplendent Venus. Adam warns Eve that he sees

> From yonder blazing Cloud that veils the Hill
> One of the heav'nly Host, and by his Gait
> None of the meanest, some Great Potentate
> Or of the Thrones above, such Majesty
> Invests him coming. (11.228-33)

When Venus appears to Aeneas to urge him to Carthage, she has disguised herself as a huntress, and Aeneas recognizes her as his mother only as she leaves him:

> When she turned,
> Her neck was glittering with a rose brightness;
> Her hair annointed with ambrosia,
> Her head gave all a fragrance of the gods;
> Her gown was long and to the ground; even
> Her walk was sign enough she was a goddess.
> (1.402-409)

This allusion, for all its apparent incongruity, significantly qualifies Michael's role. Although Venus refuses to grant Aeneas the ordinary personal relationship between a son and his mother that Aeneas desires, and although Venus is in part motivated by her rivalry with Juno, she is also undeniably motivated by love for her son. Venus repeatedly intercedes with Jupiter on behalf of Aeneas and often herself gives Aeneas aid. Michael obviously is the agent of God the Father's divine justice, but the association of Michael with Venus makes us realize that Michael is, for all his military and judicial sternness, also the God the Son's agent, also the agent of divine, even parental love.

This is also the burden of the second allusion linking Michael and Venus. Having ascended the highest hill in the garden.

> Michael from Adam's eyes the film removed
> Which that false fruit that promised clearer sight
> Had bred; (11.412-14)

The allusion is to the fall of Troy. Aeneas has seen Priam slain, the Trojan forces scattered, and, frenzied, he is about to kill Helen, the cause of the Trojan War, whom he has discovered hiding at Vesta's altar. Venus appears and prevents him:

> 'And those to blame are not
> the hated face of the Laconian woman,
> the daughter of Tyndareos, or Paris:
> it is the gods' relentlessness, the gods'
> that overturns these riches, tumbles Troy
> from its high pinnacle. Look now—for I
> shall tear away each cloud that cloaks your eyes
> and clogs your human seeing, darkening
> all things with its damp fog; you must not fear
> the orders of your mother; do not doubt,
> but carry out what she commands. For here,
> where you see huge blocks ripped apart and stones
> torn free from stones and smoke that joins with dust
> in surges, Neptune shakes the walls, his giant
> trident is tearing Troy from its foundations;
> and here the first to hold the Scaean gates
> is fiercest Juno; girt with iron, she
> calls furiously to the fleet for more
> Greek troops. Now turn and look: Tritonian Pallas
> is planted there; upon the tallest towers
> she glares with her storm cloud and her grim Gorgon.
> And he who furnishes the Greeks with force
> that favors and with spirit is the Father
> himself, for he himself goads on the gods
> against the Dardan weapons. Son, be quick
> to flee, have done with fighting. I shall never
> desert your side until I set you safe
> upon your father's threshold.' So she spoke,
> then hid herself within the night's thick shadows.
> Ferocious forms appear—the fearful powers
> of gods that are the enemies of Troy. (2.601-23)

This allusion has several functions. It demonstrates once again the arbitrariness and vindictiveness of the classical gods, yet it demonstrates Venus's love for her son, and it thereby represents Michael's mission not as vindictive, but as just and loving. It is also significant (and this is the reason for so extended a quotation) for the understanding it provides us of Adam. To that vision Aeneas must submit and abandon Troy, and in doing so he takes the first step toward a new identity, toward becoming the archetypal Roman, *pater* Aeneas. That transformation demands that Aeneas dedicate himself totally to the founding of the Roman empire and to comply with the will of Jupiter. Consequently, that transformation demands that Aeneas abandon his homeland, lose his wife, deny his love for Dido and desert her, lose his father, wage a prolonged war, unwillingly, against the Italians, and die in a military camp, never, in fact, founding a city. It demands the complete subjugation of his individuality to the state. The vision that Michael shows Adam separates him from the garden of Paradise, not by its destructiveness, but by its promise. In the course of the vision Adam comes to an understanding of *his* new identity, as father of a *fallen* race. Also, like Aeneas, through the process of the vision Adam is taught the role his descendants are to emulate. For Aeneas, it is resignation to the will of the gods and self-sacrifice for the good of the state. For Adam it is spiritual discernment and trust in God, for the sake of his descendants, but also (and this is the key difference) for his own sake.

The significance of the vision of the gods destroying Troy is underscored by a second reference to it at the end of *Paradise Lost.* This brings us to Eve, who has been sleeping through much of Books 11 and 12. Allusions to the *Aeneid* suggest that her re-appearance is delayed, in part, to emphasize her importance. Eve tells Adam:

> Wearied I fell asleep. But now lead on;
> In me is no delay; with thee to go,
> Is to stay here; without thee here to stay,
> Is to go hence unwilling. (12.614-16)

Her words are those of Anchises, the father of Aeneas, who refused to flee Troy without a sign from Jupiter. This was duly supplied:

> No sooner had the old man spoken so
> than sudden thunder crashed upon the left,
> and through the shadows ran a shooting star,
> its trail a torch of flooding light. (2.938-41)

Anchises declares:

> Now my delay is done; I follow; where
> you lead, I am. Gods of my homeland, save
> my household, save my grandson. (2.701-03)

And what follows becomes one of the most famous images of antiquity, Aeneas, fleeing the flames of Troy, bearing his aged father on his shoulders, holding his young son by the hand. This image was especially celebrated during the Roman Empire, for it expresses the devotion of youth, strength, and military prowess to the service of empire and of patriarchy. What is missing from this image is Aeneas's wife, Creusa, who does not escape Troy. She follows her husband, her son, and her father-in-law as they flee, but she becomes separated from them and is killed. Eve, of course, leaves paradise with Adam, and her association with Anchises makes Adam's and Eve's final view of Paradise an especially complex image:

> They, looking back, all th' eastern side beheld
> Of Paradise, so late their happy seat,
> Waved over by that flaming brand, the gate
> With dreadful faces thronged and fiery arms.
> (12.641-44)

This second allusion to the gods destroying Troy reminds us again of the contrast between classical and Christian gods, and reminds us that separation from Paradise, as from Troy, is a necessary step in the development of a new identity. The association of Eve with Anchises defines further that new identity, and especially distinguishes *Paradise Lost* from the *Aeneid,* for it indicates that the most important human relationship is not father and son, but husband and wife.

Milton uses the *Aeneid* to define for the reader the peculiar character of his epic. Obviously this discussion has not addressed the opinion of C. S. Lewis that the writing in Books 11 and 12 is "curiously bad," nor does it fully address the argument that the final books of *Paradise Lost* necessarily imply a decline in artistic power or reveal an unseemly haste to finish writing the poem. But it does demonstrate that, to the very end of *Paradise Lost,* Milton invokes the *Aeneid* as the standard by which to measure the argument of his own epic. And that suggests that Milton's own confidence in his artistic achievement had not diminished.

Notes

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PRODUCTIVITY OF RACCOONS IN SOUTHWESTERN WISCONSIN

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Abstract:

Age-specific reproduction was determined from 1,361 raccoon *(Procyon lotor)* carcasses collected in southwestern Wisconsin during the 1978-79 and 1979-80 trapping season (about 15 October-31 January). Litter size averaged 3.71 young, with 32% pregnancy for yearlings ($N=32$), and 91% pregnancy for older adults ($N=142$). Age-specific litter size remained fairly constant. About 10% of the juveniles ($N=100$) harvested in October 1979 were born mid-May and mid-July. Starvation and lack of subcutaneous fat reserves on 19 other juveniles suggested that raccoons conceived later than the normal February through March mating period may not survive a long winter in Wisconsin. Low testes weights, lack of sperm in smears, and non-extrusible penis indicated that juvenile males in southwestern Wisconsin are incapable of siring offspring. The sex ratio of juveniles (116M:100F) favored males ($P < 0.05$); the sex ratio of adults did not differ (96M:100F). Of the known mortality, 98% was attributed to hunting (43%) and trapping (55%). The harvest consisted of 65% juveniles, 13% yearlings, and 22% older adults. Maximum longevity approached 10 years; few raccoons (5%) survived more than 5.5 years.

For about 30 years the Wisconsin Department of Natural Resources stocked raccoons to increase the size of the population, with no apparent success (Woehler 1957). Then, during the 1960s the raccoon population increased to the point where during the 1970s they caused damage to summer homes, agricultural crops, waterfowl nests (Woehler 1957), and young muskrat *(Ondatra zibethicus)* populations (Dorney 1954). Concurrently, interest in hunting and trapping raccoons in Wisconsin increased due to increasing pelt values. Estimated fur purchases ranged from 53,000 raccoon pelts in 1967 to an average of over 94,600 pelts during the following 10 years. Of 39 states reporting in 1976, Wisconsin ranked 4th in the harvest of raccoons (Inter. Assoc. Game and Fish Conserv. Comm. 1977, unpubl. report). Such trapping pressure led to the objective of this study, which was to determine age-specific reproduction of raccoons in southwestern Wisconsin.

C. M. Pils, L. E. Nauman, and K. D. Hall advised and reviewed the manuscript, T. Zeisler computerized the data, and trappers, hunters, and furbuyers supplied raccoon carcasses. The University of Wisconsin-Stevens Point, and the Wisconsin Trappers Association provided financial support.

STUDY AREA

Raccoon carcasses were collected within a 13-county region of southwestern Wisconsin. The region is characterized by open hills with broad ridges in southern regions to deeply incised valleys with narrow ridges in the north (Hole 1977). Croplands are found on ridge tops and valley floors; intervening slopes are wooded.

Methods

Reproductive organs and upper mandibles of 1,361 raccoons were collected during the 1978-79 and 1979-80 fall hunting and trapping seasons (about 15 October-31 January). About 75% of the sample was collected from cooperating furbuyers once/week; the rest was saved by trappers and hunters who were instructed how to collect and store relevant organs. Most raccoons (98%) were trapped or shot, but road kills (2%) and 4 starved animals also were reported. Relevant organs were frozen for 2-3 months before analysis, and after sex, date of capture, cause of death, and county of kill were recorded.

Juvenile raccoons were distinguished from adults by the presence of canine root apical foramina (Grau et al. 1970), and aged to the nearest half month by tooth replacement patterns when possible (Montgomery 1964). All remaining specimens were aged by counting cementum annuli of an upper 1st premolar (Grau et al. 1970), because we found numerous accessory lines (Rice 1980) in upper incisors or 4th premolars.

The penis was examined from each male raccoon to determine if it could be extruded through the prepubital orifice (Sanderson 1950, 1961). Testes with attached epididymides were weighed to the nearest 0.1 g, and smears from the cauda examined for presence of spermatozoa. To reduce the bias in testes weight caused by body size differences, the average weight of each animal's testes (g) was divided by the greatest skull length (mm) and multiplied by 100 (Payne et al. 1966, Gipson et al. 1975).

Litter sizes were determined from placental scar counts from the previous breeding season (Johnson 1970). Females with turgid uteri were not examined because estrus tends to obscure the scars (Johnson 1970, Sanderson and Nalbandov 1973).

All raccoons aged at >1.5 years were designated as adults; racoons <1.5 years as juveniles; and those aged at 1.5 years old as yearlings. Barren adults refer to female raccoons that produced no offspring, either through failure to mate, failure of eggs to be fertilized, or loss of embryos before implantation or shortly thereafter, and without evidence of pregnancy or placental scars in the uterine horns.

Results

Reproduction

Males.—Average testes weights were greater ($P<0.001$) for adults than juveniles for each month of collection and all months combined. Testes of all 67 juveniles weighed ≤ 3.4 g and showed no apparent weight growth from October through January. Testes of yearlings reached the adult weight range (≥ 7.3 g) by October or earlier. Only 4% of 67 juveniles had mature sperm in the cauda epididymis; all 19 yearlings and 88% of 42 older adults were reproductively active. By December, all 14 adults and no juveniles possessed mature sperm. The baculum could be extruded through the prepubital orifice of all 37 adults, but none of 40 juveniles examined.

Females.—Of 214 adult females, 71% had been pregnant (Table 1). Of the 62 females showing no discernible evidence of placental

Table 1. Age-specific litter size[a] and percentage of barren females for raccoons from southwestern Wisconsin, 1978-80.

Age (years)	*Sample* N	*Pregnant* %	*Litter size* x
1.5	72	32.0	3.65
2.5	60	88.3	3.57
3.5	31	90.3	3.68
4.5	21	95.2	3.45
5.5	11	81.8	4.11
6.5	8	100.0	3.38
7.5	6	100.0	3.67
8.5	5	100.0	4.60
Total	214	71.1	3.71
2.5+	142	90.8	3.72

[a]From placental scar counts.

scars (considered barren), 79% were yearlings, the rest older adults. Of 72 yearlings, 68% were barren, as compared to 9% of 142 older females.

The mean litter size of 152 females was 3.71 (range 1-7). The mean litter size of yearlings (3.65) and older adults (3.72) did not differ ($P>0.05$), the mean number of young/yearling (1.17) was less ($t=9$, $P<0.01$, $N=152$) than for older adult (3.38) because pregnancy was 32% for yearlings and 91% for others. Age-specific litter size was fairly constant.

Late Litters.—Of 100 juvenile raccoons collected in October 1979, 10% were conceived later than the mating season of late January through mid-March in Wisconsin (Jackson 1961). Ages assigned to them and 7 juveniles collected in November 1979 indicated that late litters were born between 15 July and mid-September and were conceived from 15 May through mid-July (Table 2). These raccoons, and 19 additional juveniles, had no subcutaneous fat.

Sex Ratios

The overall sex ratio of 1,339 raccoons collected during this study was 109M:100F (52%). The sex ratio of 856 juvenile raccoons (116M:100F) favored males ($X^2=4.83$, $P<0.05$, 1 df); 483 adults were nearly equally divided by sex (96M:100F, $P>0.05$). Although the number of juvenile males per 100 juvenile females harvested monthly appeared higher than the number of adult males per 100 adult females, there was no significant difference (P >0.05).

TABLE 2. Birth and conception dates of 12 raccoon litters in southwestern Wisconsin, 1979.

Sex	*Date of capture*	*Age*[a] *(months)*	*Date of birth*	*Date of conception*[b]
F	10/29	1.5-2.0	Sep 1-15	Jul 1-15
M	10/29	3.0-3.5	July 15-31	May 15-31
F	10/29	2.0	Aug 20-30	Jun 20-30
M	10/30	1.5-2.0	Sep 1-15	Jun 1-15
M	Late Oct	1.5-2.0	mid Sep	mid Jul
M	11/13	3.0-3.5	Aug 1-15	Jun 1-15
M	11/13	3.0-3.5	Aug 1-15	Jun 1-15
M	11/13	3.0-3.5	Aug 1-15	Jun 1-15
F	Early Nov	3.0-3.5	Aug 1-15	Jun 1-15
M	Early Nov	3.0-3.5	Aug 1-15	Jun 1-15
M	Early Nov	3.0-3.5	Aug 1-15	Jun1-15
M	Oct-Nov	3.0-3.5	Unknown	Unknown

[a]Determined by tooth replacement (Montgomery 1964).
[b]A 63-day gestation period was assumed (Whitney and Underwood 1952).

Age Structure

Of 1,361 raccoons that were classified into age groups, 65% were collected as juveniles, 13% as yearlings, and 22% as older adults. Maximum longevity of males and females approached 8 and 10 years, respectively, although few raccoons (5%) survived more than 5.5 years.

No differences were apparent when age ratios were compared to method of capture ($P>0.05$), but 86% of 22 raccoons killed by vehicles were under 1 year old (Table 3). The juvenile:adult ratio remained relatively constant through December but indicated that there may be a greater percentage of adults harvested in January.

TABLE 3. Age composition of raccoons from southwestern Wisconsin, 1978-80.

Type of mortality	*Sample* N	*Juveniles* %
Hunted	462	64
Trapped	543	65
Vehicle kill	22	86
Unknown	334	62

Overall, 98% of known mortality resulted from hunting (43%) and trapping (55%). Road kills accounted for the remaining 2%. Equal numbers of both sexes were harvested by hunting and trapping.

DISCUSSION

Reproduction

Testes of males from southwestern Wisconsin do not reach adult size or produce sperm until at least the end of the 1st year of life, as suggested for North Dakota (Fritzell 1978) and Manitoba (Cowan 1973). Juvenile males therefore probably contribute very little to the annual recruitment in southwestern Wisconsin. However, most juvenile males in Illinois are thought to sire most litters produced from second ovulations (Sanderson and Nalbandov 1973). Similarly, Johnson (1970) found that most males have adult-sized testes during the 1st breeding season in Alabama. The relatively short frost-free season and the long cold winters in the northern portion of the raccoon range may retard the attainment of physical maturity necessary for breeding during the 1st year of life (Fritzell 1978).

Of 72 yearling female raccoons, 32% bred, compared to 54% in Michigan (Stuewer 1943*a*), 0% in Washington (Scheffer 1950), 40% in Texas (Wood 1955), 9% in Alabama (Johnson 1970), 41% in Manitoba (Cowan 1973), 14% in North Dakota (Fritzell 1978), 36-73% in Illinois (Sanderson and Nalbandov 1973, Junge and Sanderson 1982, Fritzell et al. 1985), and 66% in Missouri (Fritzell et al. 1985). Annual variations in pregnancy rates was wider in yearlings (38-77%) than in adults (68%-96%) in Illinois and Missouri (Fritzell et al. 1985). Sanderson and Nalbandov (1973) concluded that yearling females from Illinois either conceive at the same time as adults during their 1st estrus period or do not breed until the next breeding season. Johnson (1970), Cowan (1973), and Fritzel (1978) indicated that yearlings conceive somewhat later in the year than do adults. Two groups of females, late-maturing juveniles and reovulating adults, may be reproductively active throughout most of the spring and summer (Fritzel 1978). In southwestern Wisconsin, about 10% of all juveniles harvested in October 1979 resulted from late litters conceived from mid-May through mid-July, indicating that some females are ovulating in a 3-month period during the summer.

If adverse weather conditions prevent early spring conceptions, litters from 2nd ovulations are born in the fall (Steuwer 1943*a,* Berard 1952, Whitney and Underwood 1952, Lehman 1968, Schneider et al. 1971). Sanderson and Nalbandov (1973) noted that about 16% of the juvenile raccoons purchased by furbuyers in the fall following the abnormally severe spring weather of 1960 in Illinois were born from August through October. In Manitoba, 14% of births were as late as the 1st week of September (Cowan 1973). Fritzell et al. (1985) observed 21-55% of yearlings and 22-55% of adults with 2 sets of placental scars, at least 1 of which was unsuccessful through resorption, abortion, or loss soon after birth (Sanderson and Nalbandov 1983). Females could ovulate again 1-6 months later (Whitney and Underwood 1952, Schneider et al. 1971, Sanderson and Nalbandov 1973). About 10% of the raccoons collected in October 1979 in southwestern Wisconsin were juveniles conceived from 2nd ovulations from May through July. Although deep snows during the normal raccoon mating season in February may have impeded the successful movement, location, and mating of receptive raccoons during the winter of 1978-79, the exact causes remain unknown. Malnutrition and disease in winter adversely affected the success for 1st-estrus matings in Manitoba (Cowan 1973), and both were reported in southwestern Wisconsin.

If we consider the energy demands during pregnancy, the 8-10 week nursing period, and the lengthy female-young relationship (Schneider et al. 1971, Fritzell 1977), late litters would be especially maladaptive in the severe winter climates in Wisconsin. Litters produced in the milder environments of the southern United States may be benefited by 2nd ovulation and fertile juvenile males, but survival of juveniles whelped from late breeding females would add little to the total annual recruitment in Wisconsin. Our observations of 4 starved juveniles and 19 others lacking subcutaneous fat reserves suggests that some young raccoons may not survive a long and severe winter in Wisconsin. The body weight of juveniles in Manitoba decreased about 30% over winter, and winter mortality was possibly as high as 60% for this age class (Cowan 1973). Raccoons without placental scars weigh less than others (Sanderson and Hubert 1981, Fritzell et al. 1985). Delayed maturity and larger litters in northern latitudes apparently compensate for recruitment from late breeding yearlings in southern ranges; but age-specific litter size is relativley static, contributing little to annual changes in recruitment (Fritzell et al. 1985).

Hunting and trapping accounted for 98% of known human-related mortality of raccoons in southwestern Wisconsin. Only 2% of the raccoons reported were killed by vehicles; although an unknown number of road kills may go unreported, it appears that this is not an important mortality factor.

Age Structure

Raccoon populations in northern states have proportionately more juveniles and a more rapid turnover rate than those in southern areas (Johnson 1970). The 65% juveniles collected in southwestern Wisconsin agrees with reports of juveniles ranging from 41% to 70% of the harvest in northern areas (Stuewer 1943*a,b,* Sanderson 1951, Llewellyn 1952, Fritzell et al. 1985), and reflects differences in productivity, greater mortality from severe winters, intensive hunting and trapping pressure, and disease noted in northern areas over southern raccoon ranges (Johnson 1970). Variation in pregnancy rates strongly affects annual recruitment (Fritzell et al. 1985) because of the high number of yearlings in the breeding population.

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HISTORICAL CHANGES IN WATER QUALITY AND BIOTA OF DEVILS LAKE, SAUK COUNTY, 1866-1985

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Abstract

Concerns have been expressed in recent years that the water quality of Devils Lake may be deteriorating. As a result, water quality and biological studies of the lake were initiated in 1981 to determine its status. Examination of historical and recently collected physical and chemical data show considerable variation in some parameters but no clear trends toward poorer conditions were found. However, available historical data suggest changes in biological communities have occurred which may indicate or could cause poorer water quality conditions. These changes include (1) alteration of the aquatic plant community brought about by the invasion of Eurasian milfoil *(Myriophyllum spicatum),* (2) a change in fish population composition and relative abundance, and (3) an increase in phytoplankton biomass at certain times of the year. Interrelationships between these biotic changes and their possible effects on the water quality of Devils Lake are discussed.

INTRODUCTION

As a scenic and recreational resource, Devils Lake (Devils Lake State Park, Sauk County) has always been recognized as one of Wisconsin's finest. The lake's clear water has made it extremely popular with swimmers, boaters and scuba divers. Its fish population has historically provided good fishing opportunities. The unique value of Devils Lake can be attested to by over one million annual visitors to the park. However, recent observations of the lake's condition have given rise to concern that water quality may be deteriorating.

In 1981, a Wisconsin Department of Natural Resource (DNR) Task Force was appointed to investigate the problem. The Task Force concluded, based on the historical data available, that there probably had been some decline in the quality of Devils Lake and recommended that a basic data collection program be initiated to monitor conditions in the lake (WDNR Task Force Report, June 1981). A data collection program carried out jointly by park personnel, DNR Southern District staff, the Bureau of Parks and Recreation, and Research got underway in 1981 and continued through 1985.

This report is a compilation and analysis of the historical and recent data sets on Devils Lake. The data presented were derived from many different sources other than our own work, and we have tried to give other investigators due credit. Using information from so many sources unavoidably introduces data bias to varying degrees due to differences in methodologies. However, we cannot review all methods used by different investigators here and have chosen only to discuss methodologies where we felt differences were of significance. Details on methods used can be found in cited documents.

We have attempted to interpret this data,

TABLE 1. Morphometric data for Devils Lake, January, 1984.

Lake Area	*369 Acres*
Area < 3 ft.	3%
Area > 20 ft.	77%
Shoreline length	3.55 mi
Maximum depth	47 ft
Mean depth	30.4 ft
Volume	11,210 acre-ft
Watershed Area	2.65 mi²
Elevation (Long-term mean)	962.6 ft (House, 1985)

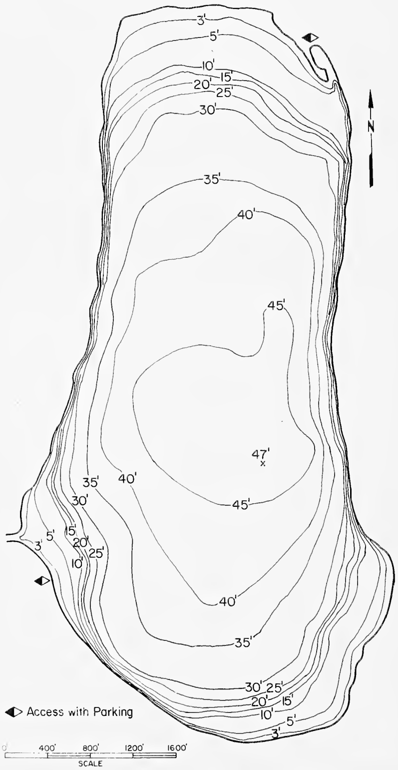

Fig. 1. Morphometric map of Devils Lake. Measurements made in January 1985, by G. Wegner and G. Quinn. Drafted by E. Eaton.

where possible, in light of the alleged changes in the lake's water quality. As is generally the case with historical water quality data sets, gaps in data collections made interpretations difficult and in most cases, prevented identification of long-term trends. We hope the information presented in this article will serve as a guide for future studies of the lake and in efforts to prevent its deterioration.

The Lake and Its Watershed

Devils Lake has a unique geologic history and origin, the story of which fills many volumes (Martin, 1916). It lies in a basin with steep rocky bluffs along the east, west, and south shorelines. Because the lake has no outlet, variations in annual precipitation are reflected in rather dramatic water fluctuations. A range in lake levels of nearly 11 feet has been recorded over a 56 year period with an average annual water-level fluctuation of 2.64 feet (House, 1985). Minimum and maximum stage were recorded in 1965 and 1973, respectively (House, 1985). Thus, morphometric data (Table 1) are dependent upon lake stage. Devils Lake is a 369 acre seepage lake with an average maximum depth of 47 feet (Figure 1).

Nearly all of the Devils Lake watershed is now in State of Wisconsin ownership, although a few small privately owned parcels still remain. The Devils Lake watershed is characterized by small size, steep relief, large areas of impervious rock surface or shallow soils and hardwood forest cover type (Plate 1, Figure 2). Because of these characteristics, surface runoff from the watershed to the lake is very rapid during storm events and snowmelt. The only permanent tributary enters the lake in the southwestern corner, and even this stream has very little flow under dry conditions. Other drainage paths are normally dry but can carry large volumes of water during major runoff events. The total watershed land area was 4.34 miles,² however, only 2.65 miles² now drains into Devils Lake. Since the mid-1970's, runoff

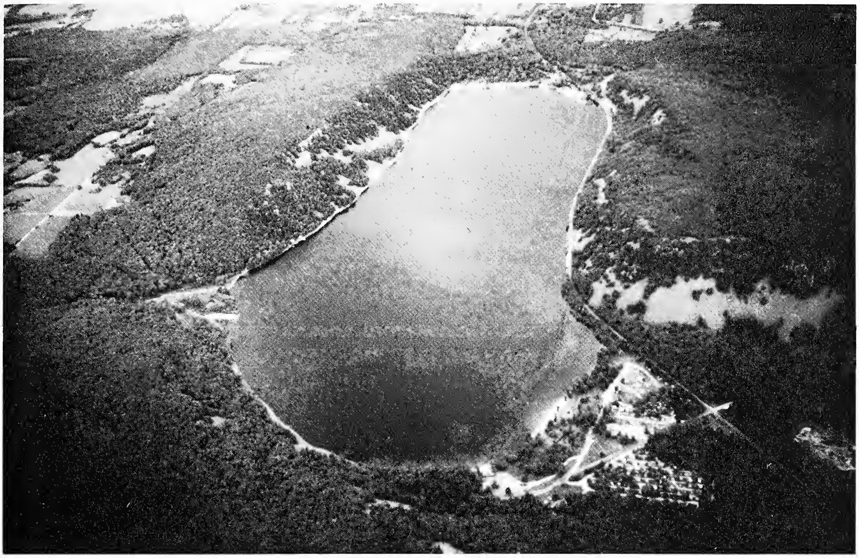

Plate 1. Air photo of Devils Lake from south.

from the northeastern subbasin has been permanently diverted to the Baraboo River.

We estimated nutrient runoff from the two main subbasins of the watershed, the southwest and the northeast, from 1970-74. Nitrogen and phosphorus concentrations in runoff were found to be similar in both subbasins (Table 2). Estimates of nutrient yields from these two watersheds (Table 3) suggested runoff coefficients were typical for forested watersheds in the U.S. (EPA, 1980). Total watershed P loading to Devils Lake (excluding atmospheric and groundwater contributions) was calculated to be 0.206 $g/m^2/yr.$ during the 1970-74 period. This was slightly above the "permissible" rate as described in various lake loading models (Dillon, 1975; Vollenweider, 1975; Uttormark and Hutchins, 1980). However, permanent diversion of the northeast subbasin drainage from the lake has reduced the annual watershed nutrient loading to the lake by about 40 percent. Nutrient loading rates now appear to be well within the "permissible" range.

Results

Historical Record—Physical and Chemical

Devils Lake is dimictic with thermal stratification beginning in late spring or

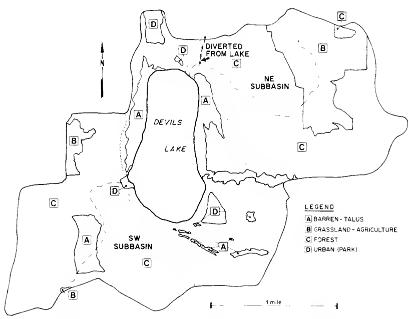

Fig. 2. Watershed map of Devils Lake. Drafted by S. Mace.

TABLE 2. Nitrogen and phosphorus concentrations in drainage waters to Devils Lake, 1970-1974. Sample nos. in parentheses.

	Southwest Subbasin		*Northeast Subbasin**	
	Range	*Mean*	*Range*	*Mean*
Organic N-mg/L	.03-1.36(29)	.29(29)	.09-.69(12)	.45(12)
Inorganic N-mg/L	.09-1.25(29)	.42(29)	.00-.91(12)	.26(12)
Total N-mg/L	.15-2.57(29)	.71(29)	.12-1.26 (12)	.71(12)
React. P—ug/L	5-137(29)	30(29)	5-111(12)	43(12)
Total P—ug/L	1-400(29)	50(29)	1-140(12)	60(12)

* Drainage now diverted from the lake.

TABLE 3. Estimated annual nutrient loading to Devils Lake from the watershed, 1970-1974.

	Southwest Subbasin *(1.36 mi²)*	*Northeast Subbasin** (1.69 mi²)	*Total Watershed* (4.34 mi²)
Watershed Loss, lbs/A/yr.			
P	0.22	0.26	0.24
N	3.14	3.14	3.14
Lake Loading, g/m²/yr.			
P	0.058	0.087	0.206
N	0.83	1.03	2.65

* Drainage now diverted from the lake.

early summer (Figure 3) and continuing through September. The duration of the spring overturn and the timing of the establishment of a permanent thermocline varies annually dependent upon climatic patterns. The depth of the epilimnion progressively increases from 18-20 feet in early summer to 30 feet by late summer (Figure 3). Erosion of the thermocline, resulting from the passage of periodic cold fronts (Stauffer, 1974), is evident in early fall as the mixing zone rapidly deepened in late September. Complete mixing generally is established by mid-November. Hypolimnetic temperatures vary from 48-53°F and do not appear to be correlated with spring weather data.

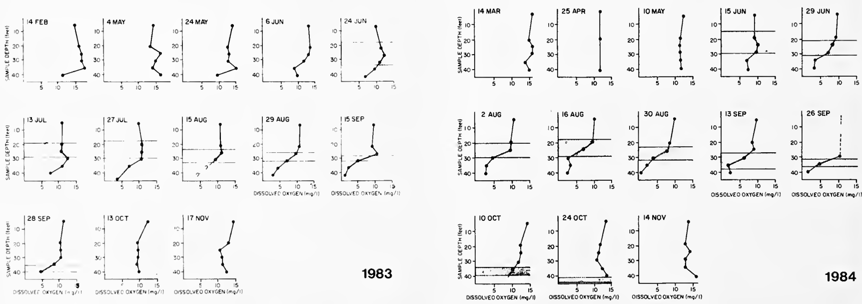

Fig. 3. Dissolved oxygen profiles for Devils Lake during a) 1983 and b) 1984 showing depth of thermocline (shaded area).

One of the most important measurements of lake water quality is water clarity or appearance. Water appearance has not been adequately measured in Devils Lake, probably because it is still clear in comparison with other southern Wisconsin lakes. However, while the written record is lacking, the collective view of many individuals is that Devils Lake is generally not as clear as it used to be. For example, scuba divers have commented upon the apparent decline in transparency in recent years.

Data to substantiate a water clarity deterioration is meager. While a considerable number of measurements of water clarity have been made over a long period of record (Figure 4), changes within seasons make comparisons difficult. Seasonal trends are evident with declining water clarity from early to late summer the rule rather than the exception. Annual trends in water clarities are less obvious although the data suggest a probable decline in water clarity during 1976-81 (Figure 5). However, clarities improved slightly in 1982 and 1985. Historically, water clarity in Devils Lake has remained very good to excellent based upon comparisons with 1140 other Wisconsin lakes (Lillie and Mason, 1983).

Dissolved oxygen (D.O.) concentration profiles within Devils Lake during the period of thermal stratification were clineograde except for occasional metalimnetic maxima (Figure 3). Epilimnetic concentrations were generally at or close to 100 percent saturation. Greatly reduced saturations occurred below the thermocline due to the decomposition and respiration processes. Over 150 D.O. profiles were collected since Birge and

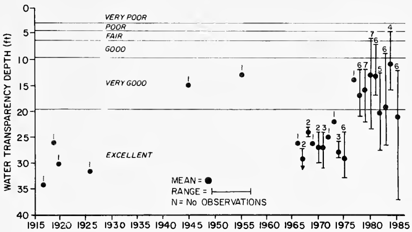

Fig. 5. Historical trends in summer water clarity of Devils Lake, Sauk County for 25 summers (July-September) from 1916 to 1985. Data sources are: Birge and Juday (1917, 19 and 26); Cline (1945); Jacob (1955); Lee (1966); WRR-DNR (1967-80); Dunst (1975); Stauffer (1971-72); Vignon and Armstrong (1974); Schlesser (1977-81); Martin (1980); and Devils Lake State Park Staff (1982-85). Water quality index based on Lillie and Mason, 1983.

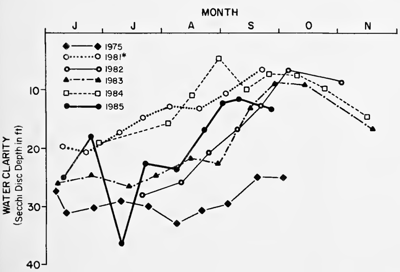

Fig. 4. Water clarity of Devils Lake for summer and fall periods of 1975; 1981-85. Data sources are listed in Figure 5.

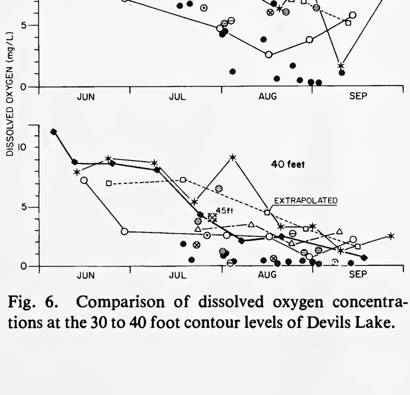

Fig. 6. Comparison of dissolved oxygen concentrations at the 30 to 40 foot contour levels of Devils Lake.

TABLE 4. Dissolved oxygen depletion rate comparisons for Devils Lake.

	Depletion Rate *Slope mg/L/day* *30 ft.*	*Slope Log mg/L/day* *40 ft.*	*Summer Water Clarity*
1907*	−0.05		Unknown
1909*	−0.07	−0.016	Unknown
1972**	−0.06	−0.017	Excellent
1975	−0.05	−0.05	Excellent
1979	−0.08	−0.013	Very Good
1980	−0.12[a]	−0.022	Very Good
1981	−0.014	−0.025	Very Good
1983	−0.02	−0.005	Very Good to Excellent
1984	−0.10	−0.008	Good to Very Good
1985	−0.02	−0.006	Excellent

* Birge and Juday data in Conway, 1972.
** Stauffer data in Conway, 1972.
[a] 0.06 mg/L/day first 69 days of stratification period.

TABLE 5. Epilimnetic nutrient concentrations of Devils Lake, Sauk County, Wisconsin.

	Total Phosphorus ug/L	*Total Nitrogen mg/L*
x ± 1 SE	23 ± 1.7	0.40 ± 0.03
Range	15-51	0.16-0.56
C.V. (%)	32	28
N (Years)	19	17

Juday's first collections in 1907. No trends in dissolved oxygen concentrations were detected. Estimated hypolimnetic D.O. depletion rates, based on D.O. concentrations at the 30 and 40 foot depths (Figure 6), were significantly higher ($P<0.05$ at 30 feet, $P<0.10$ at 40 feet) in years with reduced water clarities (Table 4). D.O. depletion rates decreased in 1983, deteriorated (increased) in 1984, and improved again in 1985, exhibiting rates very similar to those measured during 1975. Thus, D.O. concen-

TABLE 6. Comparisons of epilimnetic total phosphorus concentrations (ug/L) from Devils Lake for various years. Superscript numbers refer to frequency of sampling.

Years	*July*	*August*	*September*	*October*	*Source*
1971-72	12[2]	11	—	26	Stauffer, 1974
1978-80	20[3]	20[3]	20	—	DNR-BLP; WRR
1981	13	12	11	—	DNR-BLP
1982	9	10	27	25	DNR-DLSP
1983	13[2]	17	17	25	DNR-DLSP
1984	—	22	24	29	DNR-DLSP
1985	15	16	—	—	DNR-DLSP

Data Source Codes: DNR-BLP = Benchmark Lake Program
DNR-DLSP = Devils Lake State Park
DNR-WRR = Water Resources Research Section

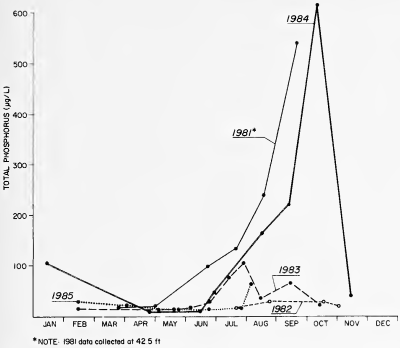

Fig. 7. Total phosphorus concentrations (ug/L) in the hypolimnion (40 foot depth) of Devils Lake, 1981-85.

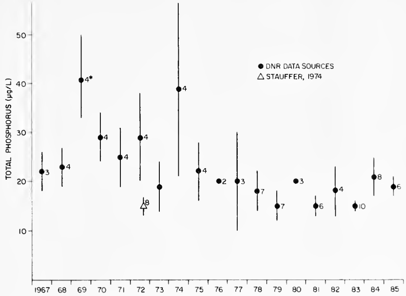

Fig. 8. Epilimnetic total phosphorus concentrations ($\bar{X} \pm$ 1SE) in Devils Lake during 1967-85. (N) = number of sampling dates. *Laboratory precision during 1969 was low. Data reported to nearest 0.1 mg/L phosphate; those values were within ±16 ug/L phosphorus.

trations appear to have fluctuated annually with no trend discernible.

Nutrient concentrations in Devils Lake are quite low (Table 5) and are among the lowest on record for lakes in the region (based on Lillie and Mason, 1983). Epilimnetic phosphorus concentrations generally increased from summer to fall (Table 6) as did hypolimnetic values (Figure 7). Increased hypolimnetic phosphorus concentrations were observed in 1981 and 1984. Volume weighted estimates of total in-lake phosphorus mass indicated an overall increase of 100-400 kg in the water column from early summer to fall turnover (Table 7). This corresponds with an observed average increase of 180 kg from spring to fall. However, spring phosphorus levels were consistently low (mean 15 ug/L) and no clear trend was evident in the 19 year record of epilimnetic phosphorus concentrations (Figure 8).

Lowest total nitrogen concentrations occurred during spring turnover (mean 0.35 mg/L) and highest levels occurred during the fall turnover (mean 0.47 mg/L). Occasional extreme values have been recorded in surface waters during late summer algae blooms (2.12 mg/L maximum), whereas higher

TABLE 7. Comparison of computed (estimated) mass of inlake total phosphorus for Devils Lake. Values in kilograms of phosphorus.

Years	*June*	*July*	*August*	*Sept.-Nov.*	*Sources*
1971-72		144-224	196	284	Stauffer, 1974
1974		140-205			Vignon and Armstrong, 1977
1978-80		265-303	255-583	243-278	DNR-BLP; WRR
1981	275	181	246	202	DNR-BLP
1982		140	186	291-337	DNR-DLSP
1983	191-192	216-218	240	240-296	DNR-DLSP
1984	149-165	N.S.	347	408-579	DNR-DLSP
1985	160	189	219		DNR-DLSP

Data Source Codes: DNR-BLP = Benchmark Lake Program
DNR-DLSP = Devils Lake State Park
DNR-WRR = Water Resources Research Section

levels were typically found in the hypolimnion. Epilimnetic nitrogen concentrations appeared to have increased steadily from 1967 to 1971 after which they appeared to have oscillated back and forth about the mean (Figure 9). No indications of further increases were evident. The lake appeared to be phosphorus limited as total nitrogen to phosphorus ratios generally exceeded 10:1.

Other commonly reported water quality parameters were relatively stable, both seasonally and by depth throughout the period of historical record. Values generally were lower than normal for the region (Table 8). No clear trends are apparent in any of these parameters during the period of record (Figure 10). Magnesium concentrations appeared to have more than doubled from 3 to 8 mg/L during 1967 to 1980 but the most recent data (1983-85) were similar to the earliest data. Conductivities have been quite variable but appeared to have been higher than normal during 1979.

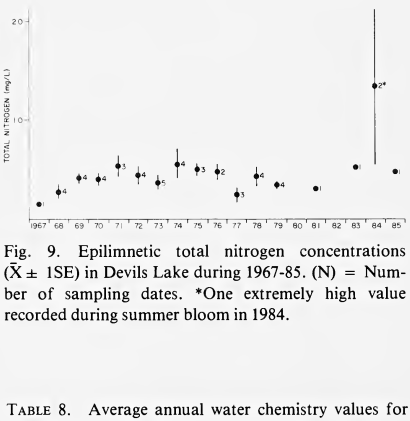

Fig. 9. Epilimnetic total nitrogen concentrations ($\bar{X} \pm$ 1SE) in Devils Lake during 1967-85. (N) = Number of sampling dates. *One extremely high value recorded during summer bloom in 1984.

Table 8. Average annual water chemistry values for Devils Lake. All values in mg/L unless otherwise noted.

Parameter	*N*	*Mean*	*SE*	*CV %*
Alkalinity	57	22	0.4	14
Calcium	48	7.5	0.4	33
Magnesium	48	4.5	0.3	46
Sodium	50	2.7	0.2	60
Potassium	49	1.3	0.1	55
Chlorides	53	2.2	0.1	34
Conductivity**	45	88	2.1	16
PH[a]	65	7.3*	0.03	3

* Arithmetic mean.
** umhos/cm
[a] pH units

Historical Record—Fish

The fish population of Devils Lake represents the pinnacle of the food chain and as such has exerted a great ecological impact on the lake. What the "original" population was like before any human manipulations took place is unknown, but a population of forage, panfish and game fish species similar to that of other southern Wisconsin lakes (Becker, 1983) probably existed in presettlement times. Because of the lake's geologic history, its fish population most likely originated from the Wisconsin River drainage system. Early settlers may have found lower standing crops of fish than in other lakes in southern Wisconsin due to the unique morphometric characteristics and relatively low fertility of the lake.

Historical records show 32 different fish species caught, observed, or stocked in Devils Lake between 1866-1985 (Table 9); while past errors in identification cannot be ruled out, data given in Table 15 are believed to be reasonably accurate.

Earliest records on the fish species inhabiting Devils Lake and early accounts of fish stocking were gleaned from local newspapers by Ken Lange, Devils Lake State Park Naturalist. The *Baraboo Republic* reported that the lake in 1866 had great numbers of "perch, bass and pickerel, some of the latter weighing twenty-five pounds." The species of "bass" referred to here is uncertain, but the "pickerel" weighing 25 pounds were surely northern pike. An undated brochure on the Cliff House, a resort on Devils Lake from 1873-1904 lists "pike, pickerel, black bass, yellow perch, sunfish and minnows" as present in the lake. Again, whether the "black bass" were largemouth

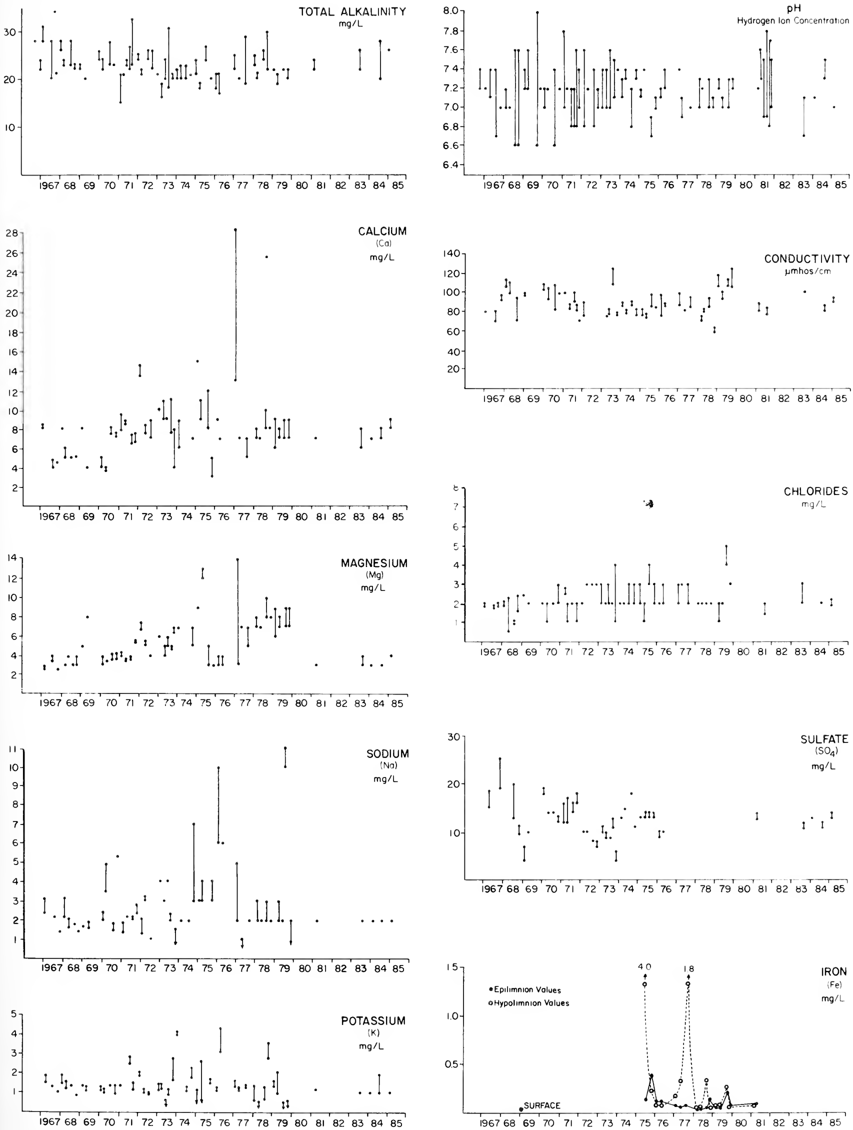

Fig. 10. Historical trends in selected water chemistry parameters for Devils Lake during 1967-85. Ranges for surface and hypolimnetic sample values are given for: a) total alkalinity, b) calcium (Ca), c) magnesium (Mg), d) sodium (Na), e) potassium (K), f) pH, g) conductivity, h) chlorides (Cl), i) sulfate (SO_4), and j) iron (Fe).

TABLE 9. Historical record of fish species inhabiting or introduced into Devils Lake. Numbers indicate information source, S denotes stocked fish; stocking records after 1944 not included.

Species	1866	1873	1875	1878	1879	1884	1885	1894	1895	1896	1897	1904	1905	1906	1912	1922
White Sucker *Catostomus commersoni*					1						1	1	1			
Mimic shiner *Notropis volucellus*																
Bluntnose minnow *Pimephales notatus*																
Northern pike *Esox lucius*	1						1									
Yellow perch *Perca flavescens*	1						1		1							
Walleye *Stizostedion vitreum*						1 S	1									
Iowa darter *Etheostoma exile*																
Smallmouth bass *Micropterus dolomieui*																
Green sunfish *Lepomis cyanellus*																
Bluegill *Lepomis macrochirus*																
Rock bass *Ambloplites rupestris*							1									
Black crappie *Pomoxis nigromaculatus*																
White crappie *Pomoxis annularis*																
Fathead minnow *Pimephales promelas*																
Spotfin shiner *Notropis spilopterus*																
Spottail shiner *Notropis hudsonius*																
Blacknose dace *Rhinichthys atratulus*																
Johnny darter *Etheostoma nigrum*																
Burbot *Lota lota*											1				1	

Species	1925-28	1931	1934	1935	1937	1938	1939-44	1945	1947	1948	1954-55	1967	1968-70	1972	1974	1978	1984-85
White Sucker *Catostomus commersoni*	7		6							9	10			13	14		16
Mimic shiner *Notropis volucellus*	7																16
Bluntnose minnow *Pimephales notatus*	7																16
Northern pike *Esox lucius*	7						8 S	8			10	11	12	13	14		16
Yellow perch *Perca flavescens*	7				8 S			8		9	10	11	12		14		16
Walleye *Stizostedion vitreum*	7				8 S	6 S	8 S	8			10		12	13	14		16
Iowa darter *Etheostoma exile*	7																16
Smallmouth bass *Micropterus dolomieui*	7				8 S		8 S				10	11	12				
Green sunfish *Lepomis cyanellus*	7																16
Bluegill *Lepomis macrochirus*	7		6 S		8 S	8 S	8 S	8			10	11	12		14		16
Rock bass *Ambloplites rupestris*	7							8			10	11	12	13	14		16
Black crappie *Pomoxis nigromaculatus*	7				8 S	8 S					10	11	12				16
White crappie *Pomoxis annularis*																	16
Fathead minnow *Pimephales promelas*												11					16
Spotfin shiner *Notropis spilopterus*												11					16
Spottail shiner *Notropis hudsonius*								8									
Blacknose dace *Rhinichthys atratulus*																	16
Johnny darter *Etheostoma nigrum*								8				11					16
Burbot *Lota lota*									3	9	10					15	

Species	1866	1873	1875	1878	1879	1884	1885	1894	1895	1896	1897	1904	1905	1906	1912	1922	1925-28	1931	1934	1935	1937	1938	1939-44	1945	1947	1948	1954-55	1967	1968-70	1972	1974	1978	1984-85
Pumpkinseed <u>Lepomis gibbosus</u>					1																							11	12				16
Largemouth bass <u>Micropterus salmoides</u>																					8 S	8 S	8 S				10	11	12	13	14		16
Brown bullhead <u>Ictalurus nebulosus</u>																											10						
Yellow bullhead <u>Ictalurus natalis</u>																																	16
Carp <u>Cyprinus carpio</u>												1																					
White bass <u>Monrone chrysops</u>											2 S						6 S																
Rainbow trout <u>Salmo gairdneri</u>									1																		10	11	12		14		
Brown trout <u>Salmo trutta</u>																												11	12	13	14		
Brook trout <u>Salvelinus fontinalis</u>			4 S												1																		16
Channel catfish <u>Ictalurus punctatus</u>																															1		
Lake trout <u>Salvelinus namaycush</u>				1 S																													
Atlantic salmon <u>Salmo salar</u>			5 S																														
"Pike"									1									6 S	6 S	6 S													
"Bass" or "Black bass"	1						1	1 S	1	2 S	1	1 S		1 S					6 S														
"Sunfish"																								8									
"Bullhead"													2										8 S						12				
"Trout"		4 S																															

1. Newspaper, *Baraboo Republic*
2. Newspaper, *Sauk County Democrat*
3. Wisconsin Conservation Bulletin
4. Newspaper, *Milwaukee Sentinel*
5. Leopold, Aldo, *A Sand County Almanac*
6. Newspaper, *Baraboo Weekly News*
7. Greene, C. W., 1935. The Distribution of Wisconsin Fishes.
8. Wisconsin Conservation Department, Fish Management Rept. No. 86.
9. Cline, WCD memo on fish survey in 1948.
10. Jacob, WCD Invest. Memo, Nos. 225 and 226.
11. Meier and Ensign, DNR 1967 fish population survey.
12. Brynildson, Ives and Druckenmiller, DNR Bureau of Fish Management Rept. No. 35.
13. Smith, DNR memo on fish survey in 1972.
14. Kirschbaum, DNR memo on fish survey in 1975.
15. Barnhardt and Jameson, personal observations.
16. Mason, DNR memo on fish survey in 1984.

or smallmouth, or what species of "sunfish" or "minnows" were there is unknown. The "pike" were no doubt walleyes. Since the Cliff House brochure is not dated, some of the fish species mentioned could have been introduced into the lake through stocking, including walleyes. Based on old newspaper accounts, habitat requirements, and possible origins of fish species in Devils Lake, we believe white suckers, rock bass, burbot, pumpkinseed, darters, and shiners were probably original lake residents.

One thing is certain, stocking of the lake began at least as early as 1873 and some species not originally found there have been introduced to the lake. "Conservationists" of the late 1800's apparently recognized the clear waters of Devils Lake as potential trout habitat, since the first species reported stocked were salmonids, e.g. brook trout, lake trout, Atlantic salmon, and probably rainbow trout. Brook trout may have already been present in the lake before they were stocked; a native population might have inhabited the southwest inlet. The lake trout and Atlantic salmon stocked most likely quickly disappeared from the lake. Rainbow trout were first reported as present in the lake in 1895 but were probably stocked much earlier.

Conservation agency workers and cooperating sportsmen of the early era believed stocking and redistributing of fish in the state's waters were good management practices, and as Table 9 clearly shows, Devils Lake did not escape their "management." Species intentionally stocked in the lake includes some besides the salmonids which may not have been there originally. White bass in all likelihood were not native, yet they were stocked on at least two different occasions. Other species stocked, some of them many times, were largemouth and smallmouth bass, walleyes, northern pike, black crappies, bluegills, yellow perch, and bullheads. Of these stocked species, it appears relatively certain northern pike, yellow perch, and one of the basses (probably largemouth) were present in Devils Lake prior to stocking; stockings of some or all of the other species could have been intentional introductions. In addition to all these deliberate plantings, there certainly have been unintentional introductions of new species, in particular minnows used as bait by anglers.

The first comprehensive fish surveys in Devils Lake were made in the early 1900's by University of Wisconsin scientists. Greene (1935) reported on surveys made between 1925-1928, and examined collections made earlier by other investigators. He found 14 species, some of which had never been mentioned as present before that time. Since 1937, several studies of the fish population have been made by the Wisconsin Conservation Department/Department of Natural Resources and good records are available on fish stocking.

From 1944 to 1984, mostly walleye and trout were stocked. Trout stocking was generally viewed as very successful and provided a popular and productive fishery (Jacob, 1954 and 1955; Meier and Ensign, 1967; Brynildson, Ives, and Druckenmiller, 1970). Both rainbow and brown trout have been found to survive and grow well in Devils Lake but neither species has ever successfully reproduced there. Evaluation of the success or failure of walleye stocking program has been considerably more complicated, because naturally-reproduced walleyes also presumably exist in the lake. Walleye fishing reportedly has been good in some past years, but in recent years the walleye fishery apparently has declined, even though large numbers of walleyes were stocked.

Rough fish have apparently never been abundant in Devils Lake. White suckers are believed to have been native to the lake and were taken in early years by seining and spearing when they congregated during the spawning season. Suckers have also been captured when fish population surveys were made but never in large number except in

May, 1955, when Jacob removed 4,456 pounds from the lake. The presence of carp in Devils Lake has been noted by personal observations, but carp have never been collected during any of the fish surveys. The current status of this species is uncertain but if carp are now present it is in low numbers.

There is very little historical record of the minnow population in Devils Lake aside from a few notations of species present. Greene (1935) reported mimic shiner, bluntnose minnow, and Iowa darter as found in the lake. In 1945, minnow seining by the Wisconsin Conservation Department caught "predominately spot-tail shiner and Johnny darter." Meier and Ensign (1967) listed bluntnose minnow, fathead minnow, spottail shiner, and Johnny darter as present. Smith (1972) reported seeing "many" fathead minnows. The October, 1984, fish population survey captured great numbers of minnows, with mimic shiner, spotfin shiner, and bluntnose minnow most abundant. Other species present in lesser numbers were Iowa darter, Johnny darter, fathead minnow, and blacknose dace. Based on this information, there appears to have been some changes in minnow population composition and abundance since the early 1900's which could have an important ecological impact.

Population surveys made over the past 30 years by Jacob (1954, 1955), Meier and Ensign (1967), and Mason (1984) suggest that the fish composition of Devils Lake has changed (Table 10). These surveys indicate increases in the bluegill, pumpkinseed, and largemouth bass populations and possible decreases in perch, walleye, and smallmouth bass numbers between 1955-1984. Northern pike and black crappie numbers also may have increased during this period. The greatest increase in the largemouth bass population appears to have occurred between 1955-1967, while the greatest proliferation of the bluegill-pumpkinseed population apparently took place between 1967-1984.

The bluegill-pumpkinseed population expansion is the most dramatic and potentially ecologically significant fish population change. Newspaper records from the late 1800's do not mention bluegills and only one account mentioned pumpkinseeds (*Baraboo Republic,* July, 1879). Greene (1935) and other associated scientists captured bluegillls during their surveys of Devils Lake in the early 1900's, providing the first record of

TABLE 10. Comparison of catch of some warm-water fish species by netting surveys of Devils Lake.

Survey Date:	*May, 1954 (Jacob)*	*Apr.-May, 1955 (Jacob)*	*Sept., 1967 (Meier-Ensign)*	*October, 1984 (Mason)*
Gear and effort:	*2,250 foot seine, 2-3 in. mesh, 4 hauls. Dougle end drop net, 2 in. mesh, 8 days.*	*2,250 foot seine, 2-3 in. mesh, 5 hauls. 5 test nets, 2 in. mesh, 3 days.*	*2,100 foot seine, 1.5-2.5 in. mesh, 2 hauls.*	*1,300 foot seine, 1.5 in. mesh, 2 hauls.*
Species—No. Caught				
Bluegill	79	52	698	3,129
Pumpkinseed	0	0	22	540
Yellow perch	1,226	531	8	174
Rock bass	0	78	3	19
Black crappie	0	13	9	182
Largemouth bass	2	0	717	799
Smallmouth bass	27	29	4	0
Walleye	22	232	0	1
Northern pike	19	33	39	67

TABLE 11. Mean length of different age groups of fish species in Devils Lake compared to averages for other Southern Wisconsin lakes. Sample nos. in parentheses.

Species — Age Group		Jacob May, 1954	Jacob Apr.-May, 1955	Devils Lake Surveys Meier-Ensign Sept., 1967	Mason Oct., 1984	Mason May, 1985	Southern Wisconsin Averages Mackenthun 1949	Druckenmiller 1972
Bluegill — Age	0*				1.4(173)			
	1	4.4(6)	4.4(1)	5.4(9)	3.0(4)		5.0(97)	4.7(266)
	2		6.3(10)	6.9(9)	5.4(5)		5.6(529)	5.4(749)
	3			7.5(2)	6.5(12)	5.1(19)	6.4(1424)	6.2(930)
	4	8.5(1)	8.6(2)	8.3(3)	7.1(9)	5.9(39)	7.3(1170)	7.2(448)
	5			8.9(2)	8.3(8)	6.4(12)	8.0(422)	7.6(188)
	6		9.8(2)		8.9(7)	6.5(4)	8.8(109)	8.0(40)
Yellow perch	0*				2.7(191)			
	1				5.0(17)			5.6(4)
	2	6.4(4)	7.4(4)		6.7(21)		5.6(16)	7.5(44)
	3	7.5(3)	8.8(2)	8.3(1)	8.3(10)		7.6(190)	8.0(47)
	4		9.6(1)		9.6(11)		8.8(262)	8.4(23)
	5	9.8(5)	10.0(1)		10.7(2)		9.6(139)	
	6	11.8(3)	11.4(6)				11.1(39)	
Rock bass	0*				1.5(11)			
	1						5.2(3)	
	2				5.1(1)		5.5(61)	5.9(30)
	3		6.1(3)		6.8(3)	6.2(8)	5.8(278)	6.5(44)
	4		6.9(2)	7.9(1)	7.7(5)	7.2(16)	6.8(310)	7.8(30)
	5		7.9(1)		8.0(5)	7.4(13)	7.6(215)	8.8(25)
	6		8.5(2)			9.8(3)	8.5(72)	8.6(4)
	7		9.9(3)			10.9(1)	9.5(35)	
Black crappie	1			6.5(1)	4.9(2)		6.3(83)	5.4(116)
	2		9.7(1)	9.0(2)	7.8(28)	5.3(5)	7.2(434)	6.5(227)
	3			10.7(2)	9.3(27)	8.8(1)	7.8(708)	10.0(250)
	4		11.5(1)		11.0(7)		9.2(636)	9.5(121)
	5		11.9(1)				10.0(206)	10.5(61)
	6		13.1(5)					
Northern Pike	1	12.1(5)	13.7(1)	16.6(2)	16.2(27)			16.4(47)
	2	18.5(1)	20.2(9)	15.6(1)	21.0(10)		16.6(17)	18.7(75)
	3	23.8(3)	25.2(3)		22.9(5)		15.6(72)	22.8(44)
	4	26.5(1)	39.0(1)		24.0(1)		17.5(104)	25.6(35)
	5						20.3(102)	27.6(21)
	6				36.5(2)		22.8(83)	31.5(4)
	7		41.0(2)					
	8		41.0(2)					

* Age group 0 average length determined from length frequency.

bluegill presence in the lake. In the period from 1934-44, the Wisconsin Conservation Department repeatedly stocked bluegills, therefore, fish managers in the Department must have felt the population at that time was not providing an adequate fishery. Jacob's surveys in 1954 and 1955 indicate that the bluegill and pumpkinseed populations remained relatively low through that period, but when Meier and Ensign sampled the lake in 1967, the population increase apparently had begun. By 1968-1970, a creel census showed bluegills were the most numerous fish caught in Devils Lake, making up 39-57 percent of the catch (Brynildson, et al., 1970). The 1984 survey data (Mason) suggest the upward trend in the bluegill and pumpkinseed populations has continued to the present; 75 percent of the fish caught in the survey were bluegills and pumpkinseeds. Therefore the data indicates bluegill and pumpkinseed populations have historically been relatively low and stable in Devils Lake, but have increased greatly over the past 20-30 years.

Bluegill growth rate may have decreased as they became more abundant (Table 11). Early survey data indicate bluegills grew faster than normal for southern Wisconsin lakes. From the 1984-1985 age-length data, it appears growth rate may have slowed since 1954-1955. Length frequency data for bluegills captured in October, 1984 (Figure 11) show large numbers of small fish, with 88 percent in the 3-6 inch size range. These fish were of different overlapping age groups.

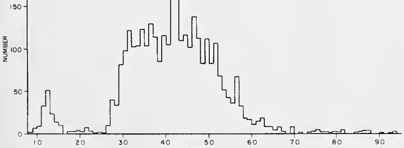

Fig. 11. Length frequency of Devils Lake bluegills, October, 1984.

Further, average length of 173 young of the year bluegills caught by shoreline seining in fall, 1984 was 1.4 inches, suggesting poor growth during the previous summer.

Lower condition factor of bluegills might also be anticipated as a result of population increase, but data limitations prevented valid statistical comparison of length-weight data from the fish surveys.

Growth rate of other panfish (yellow perch, rock bass, and black crappie) in Devils Lake remains average or above for southern Wisconsin lakes. Northern pike growth rate apparently has not changed over the past 30 years and is as good as, or better than, in other lakes in the region.

Historical Record—Macrophytes

A major change has taken place within the macrophyte community of Devils Lake. The aquatic plants of Devils Lake apparently received little attention prior to 1974, based on the recovery of only a few sketchy field notes or observations. While some collections of various shoreline emergents were made (Lange, 1984), and specimens undoubtedly exist in various herbariums throughout the state, no extensive vegetative survey of the submergent macrophyte community was accomplished until 1974 (Baker, 1975). While Baker's 1974 survey was limited to an area adjacent to the southeast beach area, it served as the foundation for assessing historical changes. Baker reported a plant community consisting of 7 species, dominated in number by *Potamogeton robbinsii* and in area by *Elodea canadensis.* Significant is his description of *Myriophyllum verticillatum* as "relatively scattered, at 1.2 to 4.5 m depths contributing little to the population of the total community." Unfortunately, and contrary to the cited paper, voucher specimens were not deposited in the University of Wisconsin herbarium and have since been lost (pers. comm. Baker). The identification of the milfoil species was confirmed by UW-Madison staff.

Systematic vegetation surveys were initiated by the WDNR in 1978 and were continued through 1983 (Bale and Molter, 1979, 1980, 1981; Bainbridge and Molter, 1982; Molter and Schlesser, 1983; annual surveys). These surveys documented the presence of several additional species including the dominance of *Nitella* sp. in deeper waters and the significant contribution of milfoil (species taxonomy in question) in shallower areas. Estimated areal coverages and distributions based on a grid overlay and rake samples showed minor fluctuations from year to year. Elodea was the most abundant species found in 1982 (Schlesser, Bainbridge and Molter, 1982).

An extensive survey of macrophyte distribution, composition, and dry weight biomass was conducted in 1984 by the Bureau of Research, Water Resources Research Section, Wisconsin DNR, (Lillie, 1986). Macrophytes covered 66 acres with an average density of 183 g/m^2 and total biomass of 51,000 kg (56 tons) dry weight. Sixteen macrophyte species were recorded (Table 12). *Potamogeton robbinsii* accounted for 50 percent of the total plant biomass while

TABLE 12. Aquatic macrophyte composition of Devils Lake (from Lillie, 1986).

	Percent Frequency (% Total Sites)	*Percent Total Biomass (% Total)*
Potamogeton robbinsii	40	46
Myriophyllum spicatum	35	20
Elodea canadensis	36	11
P. illinoensis and *P. amplifolius*	18	5
Ceratophyllum demersum	16	4
Nitella flexilus and *Cladophora* sp.	18	5
Other*	2	9

* Includes *Eleocharis acicularis, Najas* sp., *Vallisneria americana, Isoetes echinospora, Potamogeton diversifolius, P. crispus, P. pusillus,* and *Chara* sp.

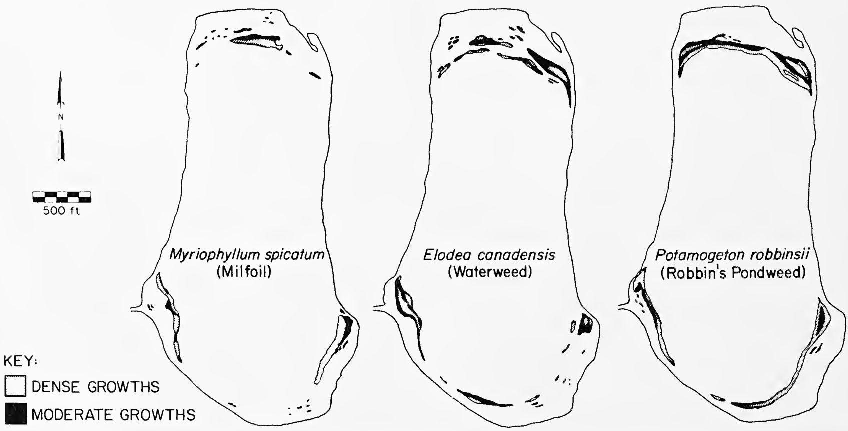

Fig. 12. Distribution of *Myriophyllum spicatum, Elodea canadensis,* and *P. robbinsii* within Devils Lake during summer 1984.

Myriophyllum spicatum and *Elodea canadensis* were next in order of importance. The distributions of these dominant species were depth dependent, forming generally contiguous bands about the lake perimeter (Figure 12). The milfoil beds extended to the surface at depths from 6-9 feet forming biological "barrier reefs" 80-160 feet wide and up to 1,000 feet long. Total milfoil acreage (7 acres) represented only 2 percent of the total lake acreage but stand densities were so dense (160-183 g/m² that the habitat structure was nearly impenetrable to divers.

Comparisons with Baker's 1974 (Baker, 1975) survey and with earlier DNR investigations, suggest that elodea has greatly declined, milfoil has greatly expanded, and *P. Robbinsii* has remained relatively unchanged within Devils Lake (Lillie, 1986). Average total biomass densities were quite similar to other fertile Wisconsin lakes (Table 13).

Historical Record—Plankton Data

The plankton community of Devils Lake is very important because of its relationship to water clarity, nutrient recycling and other biological populations. However, it has not been historically well documented.

The zooplankton record is extremely meager, consisting of only a few representative seasonal samples. The large-bodied cladoceran, *Daphnia pulicaria* and a calanoid copepod, *Epischura lacustris* have been observed in large numbers as recently as 1984. Recent collections included great numbers of smaller-bodied forms including the rotifers, *Kellicottia* sp. and *Polyarthra* sp., the cladoceran, *Bosmina* sp., and the appearance of an additional daphnia species, *D. dubia*.

The phytoplankton record is somewhat more substantial, but data are generally inadequate to draw definite conclusions. Earliest observations on phytoplankton composition were primarily of net plankton only, whereas the recent record includes the contribution of nannoplankton (Table 14). Although sampling frequency was low, the typical pattern of phytoplankton succession during the recent record was of spring

TABLE 13. Macrophyte biomass comparisons among Wisconsin lakes. Biomass based on density per m² of colonized area unless otherwise noted.

Reference	*Lake*	*# Species*	*Dry wt. g/m²*	*Notes*
Wilson (1941)	Trout Lake	36	0.075	
Wilson (1935)	Silver (Sparkling)	15	0.08	
Wilson (1935)	Muskellunge	33	0.45	
Wilson (1935)	Little John	12	0.52	
Rickett (1922)	Green Lake	27	178	
Rickett (1924)	Lake Mendota	16	202	
Sefton (1977)	Mississippi R. Pool #8	—	182	
Caflin (1977)	Mississippi R. Pool #7	—	179	In Sefton (1977)
Engel (1984)	Cox Hollow	—	100-300	0.5 + 1.5A
Engel (1984)	Halverson	15	150-300	Preharvest
Engel and Nichols (1984)	Marion Millpond	—	600	Disturbed areas
Lillie (1986)	Devils Lake	16	169-259	Dense Beds
			183	All colonized areas
			1,294	Max. per sample (2.4m depths, milfoil dominant)

TABLE 14. Summer phytoplankton associations—Devils Lake, Sauk County.

	Dominant Phytoplankton	
	By Groups	*By Major Genera*
1907	Desmid—Bluegreen	Staurastum, Anabaena, Gloeotrichia
1908	Bluegreen—Pyrrhophte	Gloeotrichia, Ceratium
1909 (early)	Bluegreen—Desmid	Gloeotrichia, Staurastrum,
(late)	Pyrrhophyte—Bluegreen	Ceratium, Nostoc
1913	Bluegreen	Gloeotrichia, Microcystis
1914-17*	Chrysophyte—Desmid	Dinobryon, Cosmocladium
1915 (late)	Bluegreen—Diatom	Anabaena, Tabellaria, Fragilaria
1923	Bluegreen	Aphanocapsa
1972	Green	(not given)
1977	Bluegreen	Aphanizomenon
1978	Cryptophyte	Chroomonas
1979	Cryptophyte—Bluegreen	Chroomonas, Aphanothoce, Aphanizomenon
1980	Bluegreen	Anabaena
1982	Bluegreen	Gloeotrichia, Anabaena and Aphanizomenon
1983	Bluegreen and Cryptophytes	Anabaena
1984	Bluegreen	Anabaena, Gloeotrichia (Some Ceratium)

Data Sources: (1907-09, 15 and 23) Birge and Juday—UW Archive material
(*1914-17) Smith, 1920
(1972) Stauffer, 1974
(1977-84) Last, unpublished DNR collection data

TABLE 15. Devils Lake Chlorophyll *a* data, 1971-1985.

Year (Source)	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*
1971 (Stauffer, 1974)			2	2				
1972 (Stauffer, 1974)	3	1^{2}	1^{3}			12		
1974 (Vignon & Armstrong, 1977)	3^{4}	1^{4}	1^{4}	1^{2}				
1977 (DNR-WRR)					7			
1978 (DNR-WRR)	7				3			
1978 (DNR-BLP)					2^{2}	3-6		
1979 (DNR-WRR)					6			6
1979 (DNR-BLP)		5-11	1^{2}	5^{2}		3	2-3	
1980 (DNR-BLP)	4	2	5	5^{2}	4-5	10-15		
1981 (DNR-BLP)		2	1-2	2-4	6^{2}	9-14		
1982 (DNR-DLSP)				2	5	2	43	22
1983 (DNR-DLSP)		4^{2}	5	2^{2}	4-5	20	9	11
1984 (DNR-DLSP)	5-6	10			6-36	13-20	13-20	10
1985 (DNR-DLSP)	7	2^{2}	2-3	2^{2}				

Note: Some liberties were taken in rounding-off chlorophyll values to the nearest whole ug/L. Superscript numbers refer to multiple samples within same month.

Data Source Codes: DNR-BLP = Benchmark Lake Program
DNR-DLSP = Devils Lake State Park
DNR-WRR = Water Resources Research Section

diatom blooms followed by late summer and early fall bluegreen blooms. Diatoms returned as dominants in late fall. Sampling was insufficient to characterize winter composition.

The bluegreen, *Aphanozomenon flos-aqua,* did not become an important component of the late summer bloom until 1977 and has occurred only sporadically since then. *Gloeotrichia enchinulata,* a colonial filamentous bluegreen and major dominant in the early record, was missing from the recent record until 1982 when it was a major dominant after an absence of nearly 70 years.

Chlorophyll *a* concentrations were less than 10 ug/L during spring and summer corresponding to good water quality conditions (Lillie and Mason, 1983). Concentrations increased steadily in late summer or early fall, and then declined as water temperature cooled. Occasional spring diatom blooms were generally of much less consequence than the fall blooms. The historical chlorophyll *a* data base is very limited as this parameter has only recently been routinely measured (Table 15). The mean concentration has been 5.9 $\pm$0.8 ug/L for 88 observations. Data are insufficient to determine long-term trends.

Discussion

The impetus which led to this study of water quality conditions in Devils Lake was the general concensus of opinion among individuals who were well acquainted with the lake that water quality had deteriorated or was in the process of deteriorating. A careful and detailed examination of the available data, both quantitative and qualitative, has lead us to conclude that some compositional changes have occurred in the biota. While no conclusive evidence was found in the data to suggest a permanent change in water quality, the biotic changes noted could be related to or lead to water quality changes.

Devils Lake appears to be better protected now than it was formerly against degradation from its watershed. External nutrient loading to the lake has most likely decreased in recent years. It is estimated that the permanent diversion of the northeast subbasin drainage resulted in a 40 percent reduction in annual watershed loading. The purchase and removal of lakeside cottages and purchase by the state of private agricultural lands, with subsequent reversion to natural vegetative cover, should likewise result in reduced loadings via run-off. External inputs via park users have probably increased, but their combined quantitative input was estimated to be minimal. There are no data on loading via direct precipitation.

The aesthetic appearance of Devils Lake is a major factor contributing to the lake's value and popularity. Water transparency and color are two critical components influencing the appearance of the lake. Color is influenced by dissolved and suspended materials and light reflection off bottom substrates. Transparency is dependent on the amounts of inorganic and organic suspended materials contributing to turbidity, on phytoplankton biovolume (estimated by chlorophyll *a* concentration) and on color. Based on a random survey of 661 Wisconsin lakes, those which appeared blue or clear generally had low chlorophyll *a* concentrations (less than 10 ug/L) and good water clarities (Lillie and Mason, 1983). Therefore, the perceived changes in water appearance observed by the public would seem to point to a change in general trophic condition. The available record of water clarity measurements seems to substantiate this perception, since the reduced water clarities in the late 1970's and early 80's coincide with the subjective observations. However, the most recent record suggests that these fluctuations in water clarity may be only temporal in nature and conditions may revert to a pre-1976 state. With only limited data available, it is not possible to determine whether a water clarity trend has developed or the changes noted in Devils Lake are within normal variability. Even with a much larger data base, water clarity trends in lakes are difficult to document, as Stewart (1976) demonstrated in his work on the Madison lakes.

As with the reduction in water clarities, the reductions in hypolimnetic oxygen concentrations observed during 1976-81 appear also to have been temporal. These anomalies may have resulted from a combination of external and internal factors. Climatic variability influences annual and seasonal nutrient loading to the lake, the duration and timing of spring and fall overturns (onset of thermocline establishment), and rate and timing of thermocline erosion. All of these factors have been demonstrated to play an important role in nutrient cycles and subsequent water quality conditions (Lund, 1972; Stauffer and Armstrong, 1984; Stauffer, 1974). In addition, variations in hydrologic loading contributed to the fluctuations in water level previously noted. These variations in water level affect the area of the lake bottom exposed to mixing and resuspension of sediments and influence the concentrations of various water chemistry parameters including hypolimnetic oxygen.

Reduced water levels and aberrations in the late summer weather pattern (i.e. early severe cold spells) could have influenced the thermocline migration mechanism (Stauffer, 1974) and contributed to early onset of phytoplankton blooms, declines in water clarity, and increases in the hypolimnetic oxygen deficit rate in some years. However, an important distinction is that while similar climatic conditions may have existed in earlier years when water levels were the same or even lower, similar reductions in water quality were not observed. Undoubtedly thermocline migration does occur in Devils Lake and it theoretically could account for much of the observed progressive increases in epilimnetic phosphorus and chorophyll *a* concentrations late in the summer. However, it does not account for the differences noted in water clarity in early summer. These differences may be due to the combined affects of climate on thermocline establishment and on diatom bloom dynamics, or on other unidentified interrelationships.

Changes in Devils Lake biota were documented which could be the result of, or could result in, changes in trophic state of the lake. *Aphanizomenon flos-aqua,* a filamentous bluegreen algae typically found in enriched trophic situations, was first observed in 1977. *Myriophyllum spicatum,* a European macrophyte, appeared in the lake sometime prior to 1974 and since has greatly expanded. The fish community has experienced a shift from the "cool water" walleye-smallmouth bass-perch population type to dominance by largemouth bass and bluegills. Also, changes in the minnow population have taken place. These biological changes, individually or in concert, could have contributed to the observed variations in water quality.

The invasion of milfoil in particular may have been a major factor. Milfoil grows in dense stands with stems and shoots reaching from the bottom to the surface at depths up to ten feet. As such, this represents a significant change in the structure of the submerged plant community of Devils Lake. Two roles are suspected of milfoil. First, the structure of the milfoil beds created a new habitat for fish that did not exist in Devils Lake prior to the invasion. The beds may serve as excellent refuges for small fish from predation by the large bass population prowling the exterior of the beds. The milfoil, by virtue of its very intricate dissected leaf structure, may harbor numerous invertebrates, thus serving as an alternative food source for the smaller fish which might normally depend upon the extensive zooplankton food resources available in the more exposed pelagic zone. Thus, milfoil beds may serve to provide both food and refuge to bluegills and pumpkinseeds, which were formerly extensively harvested by predator bass and northern pike. Changes in fish community structure due to vegetational structure have been well documented elsewhere (Wegner et al., 1983; Crowder and Cooper, 1982; Savino and Stein, 1982; and Jaeger, 1985). Therefore, the proliferation of the panfish population could be related to the invasion of the Eurasion water milfoil. The second role milfoil may have served was in the acceleration of the internal nutrient cycling rate within the littoral zone. Studies have documented that milfoil may transport nutrients from underlying sediments to the overlying water column through root uptake, stem growth and subsequent sloughing, death and lysis of plant shoots, stems and leaves (Smith, 1979; Barko and Smart, 1979; Landers, 1982). A gross estimate of the calculated input of phosphorus to the lake during the summer period based on Prentki's 1979 work on Lake Wingra shows that this mechanism might account for as much as 40 percent of the observed seasonal increase of phosphorus from spring to fall.

Additional biological influences, such as zooplankton-phytoplankton interactions (Shapiro and Wright, 1984), or hypolimnetic phosphorus retrieval by phytoplankton (Salonem, Jones and Arvola, 1984) have not been sufficiently explored in Devils Lake and are also possible contributers to water quality variability.

Because Devils Lake is a seepage lake with no outlet, nearly all phosphorus entering the lake is retained. Therefore, continued phosphorus inputs to the lake would be expected to result in a gradual buildup of phosphorus within the lake or its sediments. However, the 19 year record of annual phosphorus concentrations shows no trend toward such an increase, nor was any change noted in the spring total phosphorus concentrations. Some mechanisms apparently are functioning to remove phosphorus from the water column in Devils Lake; one of these could be iron-phosphorus co-precipitation during mixing.

Conclusions

The subjective view that water quality has declined in Devils Lake appears related to subtle changes in water color and clarity during the peak summer usage period. Because these conditions have not always developed in past years even when similar climatic and hydrologic conditions existed (including water levels), the decline in water quality which may have occurred is masked by inherent variability. Climatic variations, fluctuating water levels, an increase in internal recycling, and changes in the lake's flora and fauna are the primary suspected causes for the periodic declines in water clarity that have been observed.

Studies have been initiated to further investigate trophic interactions in Devils Lake. Wise management of this valuable resource will depend on gaining a better understanding of ecological relationships in the lake system.

Acknowledgements

We acknowledge the work of the many Devils Lake investigators who preceded us and sincerely hope we have not omitted anyone's contribution in this historical data analysis. Our thanks go to all the DNR personnel who assisted us with recent data collection efforts, but especially to Devils Lake State Park staff for their cooperation. Funding assistance for data collection came from the Bureau of Parks and Recreation, and the DNR Lake Management program provided funds for publication of this report.

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SUPPLEMENTAL DISTRIBUTION RECORDS FOR WISCONSIN TERRESTRIAL GASTROPODS

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The publication of distribution maps for the terrestrial gastropod fauna of the Eastern United States (Hubricht, 1985) is a milestone in determining probable ranges and focusing on where there may be actual distribution gaps or simply a lack of collecting.

As an aid to those who may wish to expand knowledge of the Wisconsin fauna, the following list of supplemental county records has been prepared from the mollusk collection of the Milwaukee Public Museum. The sequence of species follows Hubricht (1985). New county records for a total of 53 species are given including 15 new state records. Mr. Leslie Hubricht graciously consented to confirm these records by examining the specimens, and all the following records are accepted by Mr. Hubricht as being accurate.

I am very grateful to Mr. Leslie Hubricht, Meridian, Mississippi, for checking the identifications; to Alan Solem, FMNH, Chicago, for reviewing the manuscript; and my fellow workers at the Milwaukee Public Museum for all the assistance they have provided.

CARYCHIIDAE

Carychium exile exile H. C. Lea, 1842 Fond du Lac, Lafayette, Milwaukee, Ozaukee.

Carychium exiguum (Say, 1822) Marquette, Milwaukee, Ozaukee.

COCHLICOPIDAE

Cochlicopa lubrica (Muller, 1774) Milwaukee, Waukesha.

Cochlicopa lubricella (Porro, 1838) Jefferson, Milwaukee, Sauk, Washington, Waupaca, Winnebago; not recorded from Wisconsin in Hubricht (1985).

Cochlicopa nitens (Gallenstein, 1848) Milwaukee, Winnebago; not recorded from Wisconsin in Hubricht (1985).

VALLONIIDAE

Vallonia pulchella (Muller, 1774) Milwaukee, Washington, Waukesha, Winnebago.

Vallonia excentrica Sterki, 1893 Milwaukee, Washington.

Vallonia costata (Muller, 1774) Milwaukee, Ozaukee, Washington, Waukesha.

PUPILLIDAE

Gastrocopta armifera (Say, 1821) Milwaukee.

Gastrocopta contracta (Say, 1822) Milwaukee, Ozaukee, Waupaca.

Gastrocopta holzingeri (Sterki, 1889) Ozaukee.

Gastrocopta pentodon (Say, 1821) Kenosha, Milwaukee, Ozaukee, Waupaca.

Gastrocopta tappaniana (C. B. Adams, 1842) Milwaukee; not recorded from Wisconsin in Hubricht (1985).

Vertigo milium (Gould, 1840) Milwaukee, Ozaukee.

Vertigo ovata Say, 1822 Milwaukee.

Vertigo ventricosa (Morse, 1865) Milwaukee; not recorded from Wisconsin in Hubricht (1985).

Vertigo tridentata Wolf, 1870 Milwaukee; not recorded from Wisconsin in Hubricht (1985).

Vertigo gouldi (A. Binney, 1843) Milwaukee, Washington; not recorded from Wisconsin in Hubricht (1985).

Columella simplex (Gould, 1841) Adams, Milwaukee, Ozaukee.

STROBILOPSIDAE

Strobilops labyrinthica (Say, 1817) Adams, Fond du Lac, Milwaukee, Ozaukee, Sheboygan.

Strobilops affinis Pilsbry, 1893 Milwaukee.

SUCCINEIDAE

Oxyloma retusa (I. Lea, 1834) Door, Kenosha, Milwaukee, Washington, "Lake Winnebago."

Succinea ovalis Say 1817 Door, Ozaukee, Sauk, Vilas.

Catinella avara (Say, 1824) Milwaukee.

DISCIDAE

Anguispira alternata (Say, 1816) Dodge, Kenosha, Milwaukee, Washington.

Discus cronkhitei (Newcomb, 1865) Milwaukee.

Discus catskillensis (Pilsbry, 1898) Kenosha, Manitowoc, Waukesha.

Discus patulus (Deshayes, 1830) Milwaukee.

HELICODISCIDAE

Helicodiscus shimeki Hubricht, 1962 Milwaukee, Ozaukee.

Helicodiscus parallelus (Say, 1817) Columbia, Juneau, Kenosha, Milwaukee, Ozaukee, Walworth.

Helicodiscus singleyanus (Pilsbry, 1890) Columbia; not recorded from Wisconsin in Hubricht (1985).

Helicodiscus inermis H. B. Baker, 1929 Ozaukee.

PUNCTIDAE

Punctum minutissimum (I. Lea, 1841) Adams, Iowa, Juneau, Kenosha, Lafayette, Milwaukee, Ozaukee, Waupaca; not recorded from Wisconsin in Hubricht (1985).

LIMACIDAE

Deroceras laeve (Muller, 1774) Ozaukee; not recorded from Wisconsin in Hubricht (1985).

ZONITIDAE

Nesovitrea electrina (Gould, 1841) Milwaukee.

Nesovitrea binneyana (Morse, 1864) Adams, Kenosha, Vernon.

Glyphyalinia indentata (Authors) Kenosha, Milwaukee, Ozaukee, Walworth; not recorded from Wisconsin in Hubricht (1985).

Hawaiia minuscula (A. Binney, 1840) Milwaukee, Ozaukee.

Zonitoides nitidus (Muller, 1774) Racine, Waukesha.

Zonitoides arboreus (Say, 1816) Dane, Juneau, Kenosha, Marquette, Walworth, Waushara.

Striatura milium (Morse, 1859) Walworth.

VITRINIDAE

Vitrina limpida Gould, 1850 Milwaukee, Waukesha; not recorded from Wisconsin in Hubricht (1985).

HELICARIONIDAE

Euconulus fulvus (Muller, 1774) Marquette, Ozaukee, Waupaca.

Guppya sterkii (Dall, 1888) Ozaukee; not recorded from Wisconsin in Hubricht (1985).

POLYGYRIDAE

Stenotrema leai leai (A. Binney, 1842) Milwaukee.

Stenotrema fraternum fraternum (Say, 1824) Burnett, Milwaukee, Waukesha.

Mesodon pennsylvanicus (Green, 1827) Milwaukee, Oconto; not recorded from Wisconsin in Hubricht (1985).

Mesodon thyroidus (Say, 1816) Milwaukee, Ozaukee, Waukesha.

Triodopsis vulgata Pilsbry, 1940 Waukesha; not recorded from Wisconsin in Hubricht (1985).

Triodopsis tridentata (Say, 1816) Waukesha; not recorded from Wisconsin in Hubricht (1985).

Triodopsis albolabris (Say, 1816) Burnett, Milwaukee, Ozaukee, Vilas, Waukesha.

Triodopsis multilineata (Say, 1821) Calumet.

Allogona profunda (Say, 1821) Calumet, Kenosha, Waukesha.

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THE UNUSUAL AND THE EERIE IN AARON BOHROD'S EARLY PAINTINGS: 1933-1939

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American Art of the 20th Century exhibits a wide diversity of movements and individual styles, recalled S. R. Koehler's remarks in 1880. According to Koehler, "In periods of transition, in which some men adhere to old faiths, and others tear themselves away from them . . . individualism asserts itself . . ."[1]

The widely divergent styles of the Depression Era in the United States, in which various forms of realism, impressionism, expressionism, abstract, mystical and visionary art flourished are still with us today, as John I. H. Baur predicted in 1951 in his *Revolution and Traditions in Modern American Art.* Indeed as Baur cites the view of René d'Harnoncourt, diversity and change have become permanent characteristics of our art, and it would be the "brave critic who would dare predict what the future balance between [the various] . . . modes of painting will be."[2]

Given the range of "isms" available to artists in the Depression Era, it is often hard to place individuals in one "school" or another. This is particularly true of the work of those young artists who were just beginning their artistic careers during this volatile period.

One such artist is Aaron Bohrod, who, through his lifetime, has been variously labeled as a "painter of the American Scene," a "Regionalist," a "Social Realist," a "quasi-expressionist, half-impressionist," a "surrealist realist," and, finally, a "magic realist."[3]

All of the "isms" undoubtedly could have been applied to Bohrod's art at one time or another in the early years of his artistic career. Like many artists at that time, he experimented with the range of styles available in the Depression Era. The truth is, as Margaret Fish stated, "[Bohrod] has never been anything but a realist,"[4] meaning that he has always been an exponent of representational art of one variety or another.

There is, however, something "unusual and eerie" in Bohrod's early work. It is this "unusual and eerie" element which manifests itself completely in the mature work from 1953 to the present, but that appeared only in budding form in his early works.

My interest in Bohrod's work created a curiosity to investigate the roots of his current style of still lifes of finely-detailed, tightly composed, ironic and whimsical arrangements of mundane and art historical objects painted in a trompe l'oeil technique.[5] This interest in the "unusual" in mundane reality seemed to me to be at the very core of Bohrod's current work.

The transition to this style was, in itself, unusual, in that the majority of artists working around Bohrod in the Depression Era moved from the representational to the more abstract or from the more tightly controlled to the more spontaneous. Bohrod's development was just the opposite. His early representational style is marked by a technique of painting that shows a degree of spontaneity and simplicity, which, over the years, has become progressively more structured through a strict control of painting technique, subject matter and form.[6]

Several critics and art historians have noted this development, referring to "glimmerings," and "certain intimations" and a "developing flair for detailed and precise rendering of subject matter," as well as for an "instinct for finding an unusual angle [from the] . . . worn and common place . . ." all visible in his early paintings of the 1930's.[7]

None of the critics or art historians, however, have looked closely at his early works for the specific element already present which presaged the development of his later work. In this paper I will show that "the unusual and the eerie," was, in fact, present in his early work.

I will examine the unusual and eerie aspect of Bohrod's work which, I believe, stems from his continual use and subtle underlying emphasis upon the impermanence of the material world. Bohrod's view is delineated by his repeated juxtapositions of objects of mundane reality generally recognized as symbolic of decay and age with those that are symbolic of youth, or material strength and stability.

In this context, unusual and eerie are terms which I shall use to describe and define the unsettling effect this juxtaposition has upon the viewer looking at the material world Bohrod presents in the act of "dematerializing."

Bohrod achieves this effect through the use of several techniques, such as positioning material objects at odd angles, painting in strange colors, exploiting light effects to dramatize and distort reality, painting bleak Midwest winter, night and storm scenes, presenting figures that have enigmatic facial expressions or are turned away or hidden from the viewer, and finally, by painting supposedly solid objects and architecture as disjointed pieces of representational visual information.

It is clear that, in order to make a definitive statement of this view, it would be necessary to see and study Bohrod's early works in good color reproductions. However, these materials are not presently available. Further investigation and research is needed to locate such materials. Therefore, this paper is a "work in progress," rather than a final statement of the view here proposed.

At this point, it will be useful to provide some personal biographical background on Bohrod's early life and artistic training in order to understand the roots of Bohrod's view and techniques.[8]

Aaron Bohrod was born in Chicago in 1907. He started to draw at the age of three or four, copying the comics from daily newspapers. By 12, he was attending art classes in the art school located on the bottom floor of the Art Institute of Chicago. In high school he became the staff artist for his high school magazine and in 1917-1918 he designed several posters for the World War I Liberty Bond and War Saving Stamps campaigns.

Bohrod describes his childhood family financial condition as "poor but not miserably poor." His Russian-born father bought a small grocery store in the predominantly Jewish neighborhood of the old "West Side" in Chicago to provide financial stability for his family. Aaron, aside from being a stock and delivery boy, took delight in presenting, each week, a different imaginative arrangement of grocery wares in the store's display window. He took pleasure in "watching the reaction of casual passersby" to his "first still-life arrangements" of oatmeal boxes and soup cans stacked in strange order.

This interest in the arrangement of mundane material objects and a strong need for financial stability in a time of depression, I believe, underlies Bohrod's long and consistent history as a representational artist trying to please a large, public audience as well as to satisfy his desire to communicate with them as an artist. Later acquired skills, and jobs in the commercial world, continued Bohrod's link with the representational world.

As a teenager, Bohrod attended Crane Technical High School and Junior College where he learned mechanical drawing. This skill he later used to support himself while he continued his art studies. In 1926, while at the Chicago Art Institute, Bohrod ". . . acquired everything in aesthetic education but real painting experience." In the summer of 1927, Bohrod took a job as a commercial artist for a printing house, designing book jackets and maps, quitting this job to return to his studies at the Chicago Art Institute on a scholarship.

This see-saw between commercial art jobs and fine art studies and productions continued throughout Bohrod's lifetime; indeed, it underscores Bohrod's concern with communicating with the public-at-large. Bohrod had other experiences in the world of fine art and commercial art which also led to his development of a visual "editorial" style, one in which he could make a social comment using art as his vehicle of communication.

From 1929 to 1932, with the nation in financial turmoil, Bohrod took his savings and went to New York where he spent "two . . . fragmented years" at the Art Students' League. Forced to return to Chicago to earn more funds to support his studies at the League, Bohrod took a job as Art Director of a large department store—more arranging and display of wares. He returned to the League in New York in 1931.

It was at the Art Students' League that Bohrod worked with several well-known artists of the time, including Boardman Robinson, John Sloan, Kenneth Hayes Miller, Charles Locke, Richard Lahey and Eugene Fitsch, all espousing a representational style of art.

By all accounts, it was Sloan, however, who made the deepest and most lasting impression on Bohrod and his work. It was with Sloan that Bohrod began to develop his philosophy of art, his admiration for the "ash can" style, and his interest in portraying "an 'American' art dealing realistically with life," particularly the shabbier side of city life. Bohrod also picked up some of Sloan's reportorial point of view and his insistence on the importance of drawing.

According to Bohrod, "To [Sloan], painting was only drawing with oil color." Sloan had admonished his students to ". . . draw everything you *see* or *imagine* or *dream of*, and draw in every conceivable way and with every conceivable tool." And so, Bohrod recalls, Sloan's students drew ". . . at night, in our rooms, we turned out the lights and drew strange things without being able to see our paper. We drew from memory. We drew with the left hand. We drew with both hands at once. We pretended we were Renoir and drew like him. Like Picasso. Like Matisse . . ."

Bohrod admired Sloan's "aesthetic energy, his . . . build-up of form, his ability to capture the flavor of everyday life." The closest Bohrod ". . . ever got to artists of the Stieglitz group was going up in the elevator of that building once with Georgia O'Keefe. They were all much older . . . and had aloof and elitist approaches to painting with which I wasn't comfortable." But he was aware of their work, being an inveterate gallery-goer.

Bohrod, under Sloan's influence and given his personal background and make-up and his several successful commercial art endeavors, felt ". . . more at home with the art that seemed to have something to say to the public."

Bohrod contends that he was attempting ". . . a sympathetic portrayal of commonplace life . . . taking [his] place beside the ordinary American . . . discussing his environment with a silent plea for understanding."

During his years at the Art Students' League, Bohrod was a prodigious learner. As Bohrod recalls, he got off to a bad start with Sloan, overwhelming him "with the task of criticism by volume," and a display of his commercial "slick wrist" in his classroom studies. However, Sloan eventually became supportive of Bohrod's work.

In 1930, while in Chicago working to raise funds to return to the League in New York, Bohrod entered the first of the Depression-inspired outdoor exhibitions held in Grant Park, outside the Chicago Art Institute. This was the beginning of a long career of exhibiting there. At this time, he began several lifelong and influential friendships with fellow artists, Ivan and Malvin Albright, Francis Chapin, Edgar Britton, Constatine Pougialis and William Schwartz.

In 1933, back from New York permanently, Bohrod and his wife took up residence in a kind of artist's colony on North Avenue in Chicago where each artist-family occupied a single studio space, meeting often in sketch groups.

It was also in 1933 that Bohrod won the first of many awards he would receive from the Chicago Art Institute and other museums around the country. Shortly afterwards, several curators visited Bohrod's studio, among them Robert Harshe, Director of the Chicago Art Institute, and Mrs. Juliana Force, Director of the Whitney Museum in New York. Between them, they bought several of Bohrod's works for their museums and selected others for exhibition. Bohrod's career as an artist was officially "launched."

Between 1936 and 1939, Bohrod won three commissions from the Section of Fine Arts, Public Buildings Administration of the Federal Works Agency (FWAP) to paint murals in the Illinois post offices at Vandalia (1936), Galesburg (1938), and Clinton (1939). He also received some financial support through his participation in WPA art projects from 1936 to 1938.

Bohrod won the first of two Guggenheim Fellowships in 1936 receiving recommendations for the grant from fellow artists at the Rehn Gallery in New York who had expressed admiration for his work, Edward Hopper, Reginald Marsh, Eugene Speicher and Alexander Brook. Using the Guggenheim funds, Bohrod chose to tour the United States from 1936 to 1938 rather than go to Europe, as stated in his application.

Aside from the financial rewards, the recognition, and the public acceptance it brought, Bohrod says he valued his entry into the Associated American Artists Gallery in 1939 because it provided him with the "opportunity to meet and work with artists [he] had long admired," including Raphael Soyer, George Grosz, Thomas Hart Benton, John Steuart Curry, Grant Wood and Joe Jones.

Bohrod, as stated earlier, "was interested in viewing [all the] manifestations [in the art of the '30's]." He even deliberately experimented with Cubism and Fauvism in particular, but his ". . . experimentation was quickly exhausted in the discovery for [him] that these were mannerisms unsuited to an artist who would lean on the visual world . . ."[9]

In Bohrod's opinion, although he admired Thomas Hart Benton "for the originality of his vision and for his application of a kind of baroque old-master layering on contemporary life," he also found him "grandeloquent" and "a little frightening," and chose not to follow his "powerful (but rather obvious) rhythms."[10]

Bohrod states that John Sloan's approach to ordinary settings instigated his early desire to "[look] at Chicago in the way Sloan looked at New York and Philadelphia."[11]

Sloan's view then, was the springboard for Bohrod's work of the '30's. However, as Bohrod has said himself, "In the early years, diverse periods of painting come thick and fast for the artist . . . he is never certain for long that he is on the right road, that what he is doing is what he wants to be doing for all time. The struggle for individual style is the great bugaboo of the art student and the young professional. Only when he ceases the self-conscious search for style and loses himself in subject matter that grips him does his painting style emerge." Bohrod's "concentrated and thoughtful arrangement of visual material [and] precise decision of response required for them provided the foundation on which his present work in still life rests . . ."[12]

Bohrod's experimentation with a diversity of styles while he was a student at the Art Students' League is exemplified in several of his works from 1930 to 1933. In *Greenwich Village Gas Station,* an opaque tempera, 1930, Bohrod has attempted to reduce a New York city scape to Cubist flat planes, somewhat reminiscent of Stuart Davis' early handling of similar subject matter in his abstractions of that time. In *Street Corner,* an oil painting done at the same time as the Greenwich Village scene, Bohrod worked in the manner of the "ash can" school and his mentor, John Sloan, delineating a specific city scene, employing a tighter, but still somewhat spontaneous brush stroke, with the emphasis on a closer, pictorial reality favored by Bohrod's teachers at the League. *Clifton Park "El" Platform,* a gouache, also from 1930, lies somewhere between the Greenwich Village scene and *Street Corner* in terms of the brush work employed. Bohrod appears to be experimenting here with Fauvist technique employed to delineate the "ash can" subject matter of a specific city scene. The 1933 *Abstraction,* represents Bohrod's only painting done in a totally non-representational manner and encompasses several modes of abstraction from Synchromy to a Kandinsky-like abstract expressionism to Cubism and Futurism. *Head,* in Tempera and ink, from 1932, resembles the figurative handling and painting techniques employed by the Expressionists, such as Emil Nolde and Georges Rouault; whereas, *North Avenue Beach,* a gouache from 1933 is a combination of impressionist and expressionist techniques.

Turning from these early, student experiments in a variety of styles, we can now consider four works by Bohrod from the year 1939, when, at the age of 32, he was a well-established young artist.[13]

The four works under consideration, the Clinton, Illinois Post Office Mural, *Clinton in Winter, Under the El* (mixed media), *La Salle Street at Night* (oil on gesso panel), and *Maxwell Street, Chicago* (oil on gesso panel), represent works which we will examine to discover "the unusual and the eerie" element which was the forerunner of Bohrod's paradoxically familiar and perplexingly strange and unusual still-life pictorial situations.[14]

Clinton in Winter is a mural painting over the Postmaster's door in Clinton, Illinois. The subject, as described in the FWAP bulletin, is "a readily recognizable scene in the town of Clinton. We see a section of the County Courthouse, the statue of Lincoln, and some of the business buildings around the town square. The figures in the foreground represent types of the town, such as the town merchant, and the farmer from the neighboring country."[15]

The style and technique exemplified in this mural appear typical of those selected throughout the program, one "in which the artist's opinion is subordinated to that of the patron, and the goal is the production of high-quality art objects . . . patterned on the traditional system of private patronage," which, in this case represented the tastes of George Biddle and Edward Bruce and their preference for works in the style of (among others) Thomas Hart Benton, Reginald Marsh, Boardman Robinson, Maurice Stern —and themselves.[16]

Looking closely at the mural, *Clinton in Winter,* we can discover several elements that appear unusual for a FWAP mural. True, this is a scene of the town square and some local types as described in the FWAP bulletin, however, if we examine the mural in detail, we can note some unusual elements.

Starting with the less obvious, let us look at the background. In itself, it gives us a "stage-set" feeling, as if it is a painted backdrop for the large, "real" figures in the central foreground of "the stage" painting.

The scene is winter, the trees are denuded and twisted, dead limbs stretch up behind the central figures and are silhouetted against a darkening sky that suggests an approaching storm coming in from the left of the mural. One street light stands in front of the group of trees, and another on the other side of the central square—far back and on the left of the lower mid-plane of the picture—not much light to illuminate this large area in the approaching storm.

The horizon point of the mural is quite low—suggestive of the flat, Midwest landscape. The business buildings and shops, which stretch across this horizon point from the left to just beyond the right center, are squat, dull and drab. We glimpse a church faintly through a break between the business district buildings to the left and center and the ponderously large, old County Courthouse which looms up across almost the entire right one fourth of the mural. One wonders if a visual editorial comment is being made here that between the dominance of a cold and aloof "state" (as represented by the Old Courthouse) and the importance of "Business" (as represented by the row of shops and office buildings) the supposedly comforting institution of the "Church" is somehow forced into a hazy background.

The statue of Lincoln is seen in profile, its back to the Courthouse, and, although centrally placed in the mural, the figure of Lincoln is just a statue and does not "see" the plight on the faces of the group of people in the central foreground, two of whom look directly at us.

In looking at a detail of this group we see, on the left, a woman with her hand held to her head—perhaps against the cold and wind, or as symbolic of anguish. Although wearing a nice warm fur-collared coat, her eyes are closed and the expression on her face is hard to fathom. The facial expression, combined with the hand gesture of her right hand and the obvious tugging motion of her left arm to pull her child to her, all add to an enigmatic impression of the mother-child relationship, an expression of grief, or anxiety, or some type of tension between the two and us, the viewers.

To the right of these two figures, we see the face of a very small young boy. One can only describe the expression here as wan and sad, at the least. The four remaining figures on the right side of the group are adults. Of these, the left side figure appears to be a postman, judging from his official cap—and the location of the mural in the Main Post Office of Clinton. This figure does not look at us—or anybody—just distractedly to the left side of the mural. The woman on the right, with a scarf on her head, and wearing a "fur" collared coat similar to the lady's on the left, is partially hidden from our view, in fact, we do not see her face at all. That leaves the two central male figures. The "businessman" (the glasses and clothing are emblematic of his status) wears a warm overcoat, warm gloves, ear muffs and a stylish hat. He stands behind the "farmer," his eyes downcast, not looking at us, or at the "farmer"; in fact, only the small child and the wizened, worn old "farmer" look directly at us.

There is also a visual editorial comment which Bohrod appears to be making between the "businessman"/"farmer" relationship dependent upon the positioning of the figures, the downcast eyes of the "businessman," the gesture of his right, gloved hand—which is either being raised to further avert his view of the farmer, or, at least, to defend himself in some way.

It is the facial expression and body position of the white-haired "farmer" that carries the major statement of Bohrod's visual editorial about the Depression and age, and is a counterpoint to the facial expression and position of the small boy, who also stares straight at the viewer.

The farmer leans a little to the left—off-balanced—his sagging jacket is open, exposing him to the freezing cold and revealing his worn overalls and a shirt without a tie. On his head he wears what may be either an old army veteran's cap or a railroad conductor's cap. He has something slung over his back which he holds tightly with his left hand. His face is haggard, tired and care-worn, the skin on his neck sags with age, his white mustache droops downward, and his eyes express an enigmatic emotion—perhaps deep sadness, or, at least—melancholy.

Far from "heroizing" these figures, as stated in a local newspaper at the time,[17] Bohrod has painted a visual editorial comment of not only his view of the Depression, but also of the impermanence and instability of the "real" world and life itself. His figures are, indeed, melancholic, not heroic.

As Park and Markowitz point out in their *Democratic Vistas,* "The town and its inhabitants look drab and grim . . . elements which are ". . . sometimes characteristic of Social Realism, "in direct contrast with the "cheeriness of much American Scene painting. Bohrod's *Clinton in Winter* mural reflects "social Realist criticism . . . portraying ordinary citizens as sad, strange, and even ugly, standing listlessly in dreary places . . . the victims of the Depression, or perhaps of small town life."[18]

What struck Park and Markowitz about this work was also discussed by Linda Nochlin who commented about the "strangeness" of the work—as if there was ". . . something ominous, sinister, willful and . . . alienated—alienating—about [it],"[19] making the work representative not only of the time—the Depression—but of the response of Bohrod to it as an individual.

There are other elements which add to this feeling of "strangeness" besides the melancholy portrayal of the figures, and the drabness of the town—elements that were part of Bohrod's early work which gave them the tone of unusual eeriness. In addition to this treatment of figures and buildings, Bohrod also tended to paint winter, stormy, or night scenes with the resultant mood associated with them. He also often depicted denuded and gnarled trees, large, gloomy Victorian buildings, peeling paper, crumbling and decaying buildings of wood and brick . . . in fact, the decomposition of the material world in his paintings adds to the unusual, eerie and melancholic quality.

In contrast are Bohrod's two earlier Post Office Murals, one at Vandalia, from 1936, *Old State Capitol,* which depicts another town square, this time dominated by a centrally placed view of the old state capitol of Illinois. The scene is in summer-time, and the figures are quite small and insignificant in the bucolic setting, except for one peculiar detail. One of the figures on the lawn is pointing to a window from which, supposedly, Abraham Lincoln leaped when, as a member of the State Legislature, he wished to avoid a quorum when an issue he opposed was being voted upon.[20]

The other mural, in Galesburg, done in 1938, is even more typical of the "heroic" style of portraying American pioneers—a style and subject matter even more sought after by the FWAP.

Some of the eerie and unusual qualities in the Clinton mural are more readily visible in works by other artists of the time whom Bohrod admired, Reginald Marsh, Raphael Soyer and Edward Hopper. In Raphael Soyer's *In the City Park,* 1934, the melancholic treatment of the figures is very similar to that in Bohrod's *Clinton in Winter.* The physical setting is also similar—a park with a statue that resembles Bohrod's Clinton town square setting. The suffering, Depression Era figures are also in the forefront of the painting, their expressive faces the focal point of the painting, as are the figures in the Bohrod work.

In *Under the El,* mixed media-gouache and crayons, the ominous atmosphere present in the small town during the Depression is depicted in this scene under the trestle of the Chicago elevated train. Our progress into the picture is immediately halted by an orange fence-like material resembling barbed wire. The abstract lines and patterns of the elevated trestle at the top of the picture are repeated in the shadows below, where we see a slumped-over figure of a man, his head hanging down, his arms clutching his knees, resting against one of the powerful girders of the "El." Just behind and above this figure and girder, we see the face of a young girl on a peeling advertisement on a red brick wall. On the telephone pole to the left of the girl's face hangs another smaller, torn poster. In the middle ground, center portion of the picture we see a few low-lying old buildings with weeds growing around them. We do not know if these are houses or warehouses. Even though the horizon point is low, the view of the sky is cut into narrow, vertical bands by the vertical girders of the "El" and the telephone pole. What we do see of the sky is a storm, advancing from the left of the picture to the right. The left half of the sky in the picture is gray, the right half, blue, cut in the middle by the curving sweep of the "El" from the upper foreground to the mid-background. The color in the picture seems incidental to the draughtsmanship, the emphasis being on the lines of the "El" girders, the buildings, the wire fence in the lower foreground, and the lone figure sitting on the ground beneath the "El."

There are two statements being made in this picture, consistent with Bohrod's point of view regarding the Depression, specifically, and Life, in general. Unlike the Precisionists, Bohrod's depiction of the "El" is not a positive symbol of the industrial power of America (like various artists' scenes of the Brooklyn Bridge or Sheeler's factories and granaries). The "El," the fence in front, the buildings around the figure—almost lost under the shadow of this structure, creates a prison-like atmosphere. At the very least, the figure appears small, depressed and insignificant compared to the city structures that loom around him. This is underscored by the incoming storm, since we can see that the "El" trestle is full of holes and will afford little protection for the man.

The second statement Bohrod makes is more subtle here, but directly present in his work from the '50's onward—the contrast of "age and decay"—the man under the "El" and "youth"—the artificial face on the advertisement, repeated by the contrast of the decay of the buildings, the poster and ad and the seeming stability and strength of the "El."

This interest in the contrast of the "seeming stability" of city and industrial structure (Society) and the decay through age and wear (Time) is visible in earlier and later works of Bohrod as well as in works of his contemporaries. It is at this point that we can begin to see in Bohrod's art the budding emergence of interest in "surreal" or "fantastic" effects based on everyday existence and used, as in the early works of Guglielmi and Edward Hopper, among others, as a social or personal commentary heightened by the use of these strange "surreal" touches.

This "fantastic" or "strange" view can be seen again in Bohrod's 1939 gouache, *Ogden Avenue Viaduct,* for which *Under the El* may have been a preliminary work. The whirling clouds, the curve of the viaduct and the curving stairway create an eerie "eye of the hurricane" effect. While the curving stairway does go to the top of the viaduct, it has the odd effect of going nowhere. Below the viaduct, a lone figure sits huddled against one of the supports, just as in *Under the El,* and on the right side of the work we see several shabby apartment buildings and houses. Here also, the viaduct is not seen as a heroic product of industrialization, and the figures in the picture are isolated from one another.

In an earlier city scene, *Clark Street, Chicago,* 1934, we see this emergent contrast of stability and decay. Looking at the seemingly solid brick buildings, one can see the wear and tear on wooden window sashes, awnings, foundation bricks and signs—shown here in careful detail. Even more evident, the entire street in front of these "solid establishments" is being torn up to get at the "rotten foundations" or "faulty underpinnings." The artist has even placed an "observer" of this event in a centrally located window above the workers. We meet this meticulous handling of material details and this concern with the transient and im-

Fig. 1 Waiting for the 3:30. Oil on gesso panel.

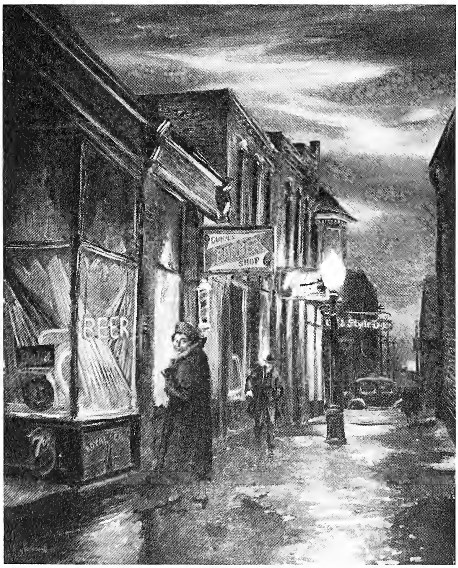

Fig. 2 Neon Nocturne. Oil on gesso panel, 20 × 16″, ca. 1940.

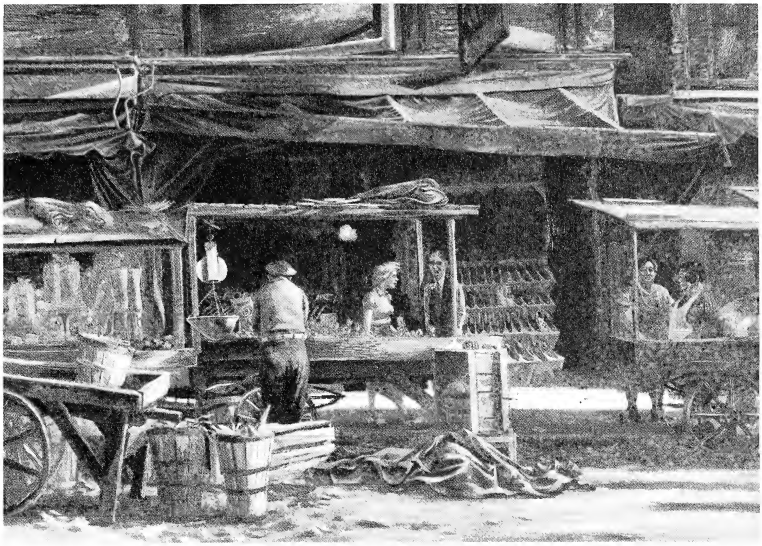

Fig. 3 Maxwell Street market. Oil, 1939.

Fig. 4 Reflections on a shop Window. Oil on gesso panel, 36 × 28½", ca. 1941.

permanent nature of life again and again in Bohrod's mature works.

Charles Burchfield's *Black Iron* watercolor painting appeared in the 1940 International Exhibition of Watercolors in the Chicago Art Institute about the same time as Bohrod's *Under the El* was done. A Peter Blume study for Eternal City appeared in that same show, in which Bohrod was also exhibiting. Numerous works by Burchfield, several by Blume, and several by George Biddle, including *Under the Elevated* had appeared in the annual International Watercolor shows at the Chicago Art Institute from the beginning of Bohrod's exhibition in that show since 1931.[21]

In Burchfield's *Black Iron,* 1935, we see a view of a ponderous metal structure that has been viewed as Burchfield's "grim indictment of industrial waste, the power of a technological society to create an inhuman desert."[22] At the very least, it is not a view of industrialization as heroic, in this, both Burchfield and Bohrod concurred.

Bohrod's *Waiting for the 3:30,* (in the Truman Library) an oil on gesso panel painted around the same time as the *Under the El,* combines several of the elements discussed previously that create an unusual and eerie atmosphere: a winter scene, decaying old buildings along railroad tracks, denuded, gnarled winter trees, and here we see industrial smoke blowing across the scene, adding another element to the social commentary. In this painting, the contrast of the decay and impermanence of "the wrong side of the tracks" is with the stylishly dressed young woman who looks at us as she clutches her bag and stands alone and unprotected in the cold.

By the end of the '30's, Bohrod's work had certain elements in it that could be called "unusual and eerie." These elements he used to convey a social comment about life in the Depression and Life in general, with particular regard for showing the contrast between age, decay and transiency with youth and the seeming solidity of the "real" world.

This eerie contrast was heightened in a series of paintings begun in the late '30's, of which *La Salle at Night* is an example. The street scene here is again old and run down, shabby. The neon light from the sign "Eat" casts a weird glow over the entire painting, picking out figures, architectural details, reflections on the damp, cobbled street. This eerie neon glow is repeated by the moon glow in the sky behind the central buildings. One is reminded of Ryder, except here we see a scene of a mundane street on the near northside in Chicago. The buildings are "tumble-down" and lean at odd angles to one another and the street, which itself runs at an angle across the picture plane; their windows are also somewhat askew, particularly in the house on the right behind the partial, oddly disengaged picket fence. In fact, everything, including the car in front of the building, seems "slightly askew." One also wonders about the character of the young lady walking towards us, arms akimbo, her dress clinging to her body, a faint smile on her face. Edward Alden Jewell described Bohrod's brushwork in these "Neon Light" street scenes as ". . . at once vivid and subtle . . . luscious, alive with texture . . ."[23] To Bohrod, "These neon nocturnes, with streets and people bathed in pink and green glow [were filled] with the strange light sometimes reflected on wet pavement" were fascinating for several years.[24]

This interest in "strange" light effects and the "weird" quality they produced can also be seen in many of Edward Hopper's night scenes which may have been the inspiration for the enigmatic mood in Bohrod's paintings. Bohrod's *Neon Nocturne* from around 1940 and *Oakdale Avenue at Night,* also around 1940 reiterate this strange luminescence of neon and moonlight, eerie reflections in shop windows, strange, often alone, female figures; shabby or old, ramshackle stores or Victorian homes; cloudy, mysterious skies; twisted, dead trees, and shop signs—neon and otherwise. Some paintings, like *La Salle Street* are close to Hopper's eerie night cityscapes, others, like *Oakdale Avenue,* recall paintings by Charles Burchfield, like *Promenade,* "infused . . . with melancholy fantasy."[25]

The odd, eerie "off-color" neon light coloration and enigmatically smiling women staring at the viewer are also suggestive of Toulouse Lautrec's and later expressionist paintings of the bistros and environs of various red light districts.

This eerie element and interest in the transiency of material reality continues to develop in Bohrod's work of the late '30's and after World War II, but turns from city and landscape scenes back to the origins—Bohrod's still-life arrangements—the shop window in his father's grocery store.

During the '30's, Bohrod painted numerous shop scenes, such as *Maxwell Street, Chicago,* without realizing the symbolic quality of the objects he painted. He only recalls being fascinated by the "jumbled bric-a-brac" and "vaguely [suggestive] . . . junky objects," and the interesting light effects and reflections in the glass window panes of antique shops.[26]

Maxwell Street, Chicago, an oil painting on gesso panel, is a close-up view of the pushcarts and small shops of this well-known wholesale market street on the old West side of Chicago. We are standing in the street looking at one section of shops and pushcarts. On the street we see the refuse and crates of produce of two grocery pushcarts in the middle and left side of the painting. The figure of the grocer has his back towards us, but it is a self-portrait of Bohrod, the grocer's son, nevertheless, in one of the first of many whimsical inclusions of himself that appear regularly in his later still-life arrangements.[27] To the left of the produce scale, in the second grocery cart are arrangements of sacks of flour, brooms and potatoes. The contents and structures of both carts are fairly detailed, as is the rendering of the dry goods shop directly behind the center cart, with its racks of men's suits and rows of sometimes matched, and sometimes whimsically mismatched, shoes. The "proprietor" of the dry goods shop stands, hands in pocket, cigar in mouth, eying an approaching young woman, perhaps a prospective customer. To the right, two heavy-set pushcart owners (they have aprons on), stand by their pushcart, which appears empty. The upper half of the painting is an intricate composition of the geometric shapes of the awnings and curtains above and on the sides of the shops, the windows above the shops, and the brick work and signs of the buildings in which the shops are located. The upper section is handled in a broader fashion than the market areas below, although the overall brush technique is not tightly detailed. Bohrod's color here seems incidental to the drawing—a Sloan-type painting . . . a lively drawing with oil color.

What is of particular interest in this painting is the detailed treatment of the material objects: the produce, baskets, produce scale, the awnings and side draperies and the reflections in the large window above the central pushcart.

We can see this interest in the texture and appearance of objects in the earlier *Landscape Near Chicago*, an oil painted in 1934 and purchased by the Whitney Museum. The detail with which materials and objects are rendered stands in a direct line to Bohrod's later trompe l'oeil technique, particularly in the rendering of the junk objects in the lower left corner of the painting, the two central jalopies and the strange materials of the somewhat odd, unreal "house," which has the appearance of being an old piece of junk, itself.

Bohrod's interest in shops and shop windows can be seen again in the 1939 gouache, *South State Street, Chicago,* in which the central subject is a watch and jewelry store and everything, including signs, buildings and people seem to be arranged around this display of wares.

Coming closer to the fascination with objects and their use as symbols is the '39 oil painting, *Still Life with Ferdinand,* painted as a deliberate grouping of Bohrod's eldest son's favorite toys.[28] They stand on an uptilted table, an angle at which they should all slide off, and they are rendered with broad brush strokes—no attempt is made to fool the eye. however, the table they are "attached" to stands just in front of an empty frame—an allusion to the unreality of the reality of painting, and to the right, we see a "real" Bohrod framed and ready for shipping resting against a wall, the paradoxically familiar and perplexing pictorial situation which Futtner mentioned in his Arts Magazine article of May, 1985.

In Reflections on a Shop Window, an oil on gesso painted ca. 1941 and *Antiques,* oil on gesso, painted ca. 1947, we have the forerunners of the objects Bohrod was to use in his later still-life arrangements—the odd, jumbled bric-a-brac physical momentos of life associated, in each of these paintings, with the process of the physical aging of people (the old ladies in both paintings), the transiency and passing of time for the physical world (the reflections of clouds, buildings—the impermanent permanent structures around us), all suggestive in Bohrod's later work of the "elusive beauty" he sought to report as an artist.[29]

In his own writings and in those of his most recent critics, Bohrod acknowledges the influences of not only John Sloan, and the Regionalists, but also of the work of his good friend, Ivan Albright, as well as recognizing the influence on his later work of the 19th Century American realists Peto and Harnett, and, more recently, on an inclusion of a surrealist or fantastic element in his work.[30]

In our review of Bohrod's early work, we have seen that his posing of pictorial situations which are at once paradoxically familiar and perplexingly strange has been part of Bohrod's work since he began arranging oatmeal boxes and soup cans in a strange order to watch the reaction of casual passersby.

Notes

[1] S. R. Koehler, "The Future of Art," American Art Review, 1:32 (1880); as cited in John I. H. Baur, *Revolution and Tradition in Modern American Art,* Harvard University Press, Cambridge, Massachusetts, 1951, p. 146.

[2] John I. H. Baur, *Revolution and Tradition in Modern American Art,* op. cit., pp. 145-146.

[3] Bohrod "labels" appear in various publications, the following list is a sampling of these appearances:

a) "painter of the American Scene": in John I. H. Baur, op. cit., p. 19.; also see Barbara Rose, *American Art Since 1900,* Praeger Publishers, New York, 1975, p. 97.
b) "Regionalist": Barbara Rose, op. cit., p. 97., also see "John Steuart Curry, Aaron Bohrod, John Wilde: Leaders in Wisconsin Art 1936-1981, "Milwaukee Art Museum, 1982, catalog, p. 25; also in "Bohrod TV gala," by James Auer, Journal Art Critic for *The Milwaukee Journal,* November, 1982 (personal clipping from Aaron Bohrod).
c) "Social Realist": "Aaron Bohrod: Still Life in the Old Boy," television program for WHA-TV, Madison, Wisconsin, November 16, 1982, written and directed by Steven Jandacek; also see Marlene Park and Gerald E. Markowitz, *Democratic Vistas,* Temple University Press, Philadelphia, 1984, p. 162.
d) "quasi-expressionist, half-impressionist": Clement Greenberg, "A Review of a Ben Shahn Exhibition," *The Nation,* 1 November 1947, pp. 431-482.
e) "magic realist": "Aaron Bohrod: Still Life in the Old Boy," WHA-TV program, op. cit.; James Auer, "Bohrod TV gala," op. cit.; "Aaron Bohrod," by Joseph L. Futtner, *Arts Magazine,* May, 1985, p. 8; John Lloyd Taylor, "Aaron Bohrod: A Retrospective Exhibition 1929-1966," Catalog, Madison Art Center, Madison, Wisconsin, 1966.
f) "surrealist realist": Joseph L. Futtner, *Arts Magazine,* op. cit., p. 8.

[4] Margaret Fish Rahill, curator, Charles Allis Art Museum, catalog, "Aaron Bohrod: Recent Paintings, July 15-August 31, 1984," funded by the Wisconsin Humanities Committee, n.p. (Tha author is also the art critic for *The Milwaukee Sentinel*).

[5] John Lloyd Taylor, Director, Madison Art Center, catalog, op. cit.; Margaret Fish Rahill, catalog, op. cit.; Joseph L. Futtner, op. cit., p. 8.; see also the illustrations in Aaron Bohrod, *Aaron Bohrod: A Decade of Still Life,* The University of Wisconsin Press, Madison, Milwaukee and London, 1966, pp. 59-298.

[6] John Lloyd Taylor, catalog, op. cit.; Joseph L. Futtner, op. cit., p. 8.

[7] Margaret Fish Rahill, op. cit.; John Lloyd Taylor, op. cit.; Joseph L. Futtner, op. cit.; and Jeanette Lowe, *The Art News* (personal clipping of Aaron Bohrod—undated), n.p.

[8] All of the biographical material and various quotations by and about Bohrod come from the following sources:

a) Personal Correspondence and telephone conversations between Carole Singer and Aaron Bohrod, Oct.-Nov., 1985.
b) "Aaron Bohrod" in *Who's News and Why*, Vol. 16, No. 2, February 1955, The H. W. Wilson Co.: New York.
c) "Aaron Bohrod Papers," Archives of American Art, Smithsonian Institution.
d) "Holger Cahill Papers," Archives of American Art, Smithsonian Institution.
e) *Aaron Bohrod: A Retrospective Exhibition 1929-1966,* catalog, Madison Art Center, Madison, Wisconsin, 1966.
f) *Aaron Bohrod: Recent Paintings,* catalog, Charles Allis Art Museum, Milwaukee, Wisconsin, 1944.
g) Harry Salpeter, "Bohrod: Chicago's Gift to Art," Esquire Magazine, March, 1940 (personal clipping of Aaron Bohrod), pp. 62-63 and 101-102.
h) Aaron Bohrod, *Aaron Bohrod: A Decade of Still Life,* The University of Wisconsin Press, Madison, Milwaukee and London, 1966, pp. 1-25.
i) Patricia L. Raymer, "Aaron Bohrod," The Milwaukee Journal Insight Magazine, November 12, 1972, pp. 18-22.

[9] Aaron Bohrod, in a letter to Carole Singer, November, 1985.

[10] Ibid.

[11] Ibid.; also see Harry Salpeter, op. cit., John Lloyd Taylor, op. cit., Margaret Fish Rahill, op. cit., and Joseph L. Futtner, op. cit.

[12] Aaron Bohrod, *Aaron Bohrod: A Decade of Still Life,* op. cit., p. 13.

[13] See autobiographical material—ftnote. 8.

[14] Joseph L. Futtner, op. cit., p. 8.

[15] FWAP Bulletin, Clinton Illinois Post Office, 1939.

[16] As cited by Edith Tonelli, *Massachusetts Federal Art Project,* Boston University Ph.D. Dissertation, 1981, pp. 24-26.

[17] Personal clipping of local paper from Mrs. Howard Lee Harrell, Clinton, Illinois.

[18] Marlene Park and Gerald E. Markowitz, op. cit., p. 162.

[19] Linda Nochlin, "Return to Order," *Art in America 69* (September, 1981), p. 76.

[20] FWAP Bulletin, Vandalia, Illinois Post Office, 1936.

[21] From Catalogs of shows at the Chicago Art Institute, 1931-1942.

[22] Ian Bennett, *The History of American Painting,* The Hamlyn Publishing Group Limited, London, 1973, p. 188.

[23] Edward Alden Jewell, New York Times review, (personal clipping of Aaron Bohrod).

[24] Aaron Bohrod, op. cit., p. 21.

[25] Suzanne Muchnic, "Welliver," a review in Book Section, *The Los Angeles Times,* Nov. 17, 1985.

[26] Aaron Bohrod, op. cit. p. 23.

[27] See cover and illustrations of Aaron Bohrod, op. cit., p. 102.

[28] Harry Salpeter, op. cit., p. 102.

[29] Aaron Bohrod, op. cit. pp. 23, & 53-55, and also in Letter to Carole Singer, Nov., 1985.

[30] Joseph L. Futtner, Op. cit., p. 8.

HAWTHORNE'S ENOCH: PROPHETIC IRONY IN *THE SCARLET LETTER*

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"A prophet or magician skilled to read the character of flame"[1] must fathom the mystery of *The Scarlet Letter*'s little Pearl, a secret first read by Roger Chillingworth, a practitioner of black arts, whose subtle torture forces the Rev. Mr. Dimmesdale to take up his principal prophetic office: the public admission that the child is his daughter.[2] In confessing to his startled flock that he has put on "the mein of a spirit, mournful because so pure in a sinful world!—and sad, because he missed his heavenly kindred" (p. 255), the minister accurately presents the effect of his anguished hypocrisy upon the congregation: they have seen him as angelic. In his study, Dimmesdale himself had observed in his glass mocking devils and "a group of shining angels, who flew upward heavily, as sorrow-laden, but grew more ethereal as they rose" (p. 145). These unhappy angels provide a significant pattern of dramatic irony for interpreting Dimmesdale's role as prophet in the romance.

During the minister's Election sermon, the community is affected "as if an angel, in his passage to the skies, had shaken his bright wings over the people for an instant,—at once a shadow and a splendor,—and had shed down a shower of golden truths upon them" (p. 249). So impressed are they, that it would not "have seemed a miracle too high to be wrought for one so holy, had he ascended before their eyes, waxing dimmer and brighter, and fading at last into the light of heaven" (p. 252). The people's apparent blurring of the distinction between what were traditionally two separate orders of creation, men and angels, is suggested earlier in the book when the sexton remarks to the minister that the great celestial letter betokens Governor Winthrop's being "made an angel" (p. 158). That Hawthorne may be accurate in presenting popular belief is supported by Puritan tombstone carving—a sample of which provides the book's striking final image—making no distinction between saved souls and angels.[3] The general mind therefore accorded with a long tradition of Neo-Platonic philosophers (Marsilio Ficino, for example), and with Milton, whose Raphael says to Adam, "Your bodies may at last turn all to spirit, / Improv'd by tract of time, and wing'd ascend / Ethereal" (*Paradise Lost,* V, 497-499). It also accorded with literature widely read in Hawthorne's day.[4]

Readers of such works as Edward Young's *Night Thoughts,* which suggested that,

> Angels are men in lighter habit clad,
> High o'er celestial mountains wing'd in flight;
> And men are angels loaded for an hour,
> Who wade this miry vale, and climb with pain,
> And slippery step, the bottom of the steep,[5]

would recognize the plight of Dimmesdale, "the man of ethereal attributes, whose voice the angels might else have listened to and answered," kept from climbing the Puritan patriarchs' "mountain-peaks of faith and sanctity" by a "burden . . . of crime or anguish" (p. 142).

Dimmesdale's identification with angels is given greater ironic force by his prophetic office for the community. While he seems to have attained what the "true saintly fathers" of the Puritan church lacked, "the gift that descended upon the chosen disciples, at Pentecost, in tongues of flame," which enabled them to communicate with "the whole human brotherhood in the heart's native langauge" (pp. 141-143), the minister is tortured by his hypocrisy. He responds to Hester's assurance that he is reverenced: "Canst thou deem it . . . a consolation, that I must stand in my pulpit, and meet so many eyes turned upward to my face, as if the light of heaven were beaming from it!—must see my flock hungry for the truth, and listening to my words as if a tongue of Pentecost were speaking!—and then look inward, and discern the black reality of what they idolize? (p. 191). Yet as he here presents himself, and as he appears at the Election sermon (XXXII), Dimmesdale does fulfill a prophetic and apostolic role. He may serve, in fact, as a type of Moses (Exod 34:29) or Stephen (Acts 6:15), both of whose countenances are illuminated like those of angels while they discourse on essentially the topic of Dimmesdale's sermon, "the relation between the Deity and the communities of mankind" (p. 249).

As he himself recognizes, the minister's "apostolic" gifts are linked to his passion for Hester and his guilt in hiding his parentage of Pearl. In the forest Dimmesdale, seemingly a failed Puritan prophet, is strengthened by Hester, whom he calls "my better angel"—perhaps in a parody of Kings 19:4—and whose resolution to run away with him makes him feel "made anew, and with new powers to glorify Him that hath been merciful" (pp. 201-202). When he delivers his sermon, he is indeed taken up by "a spirit as of prophecy" which constrains "him to its purpose as mightily as the old prophets of Israel were constrained" (p. 249), but his final revelation is not of God's relationship to men, but of his relationship to his daughter. Throughout *The Scarlet Letter,* the tensions between the minister's earthly emotions and the biblical types through which they are perceived by Dimmesdale himself and by his Puritan congregation are particularly amplified in his role as prophet transformed to angel.

Dimmesdale is supposed to belong naturally among the elders "whose faculties had been elaborated by weary toil among their books, and by patient thought, and etherealized, moreover, by spiritual communications with the better world, into which their purity of life had almost introduced these holy personages, with their garments of mortality still clinging to them" (p. 141). Since, as has been seen, the public view is that Dimmesdale might be miraculously translated to heaven, he may be likened to Elijah, a prophet so removed. But another figure is more explicitly suggested.

The Puritan imagination was enough affected by the matter of prophets lifted to heaven to have included in *The New England Primer,* the substance of which little Pearl is said to have mastered (pp. 111-112), its fifth question, "Who was the first translated?"[6] The answer is Enoch, with whom Dimmesdale contrasts himself in a sermon he dare not deliver: "I, in whose daily life you discern the sanctity of Enoch—I, whose footsteps, as you suppose, leave a gleam along my earthly track, whereby pilgrims that shall come after me may be guided to the regions of the blest,— . . . I . . . am utterly a pollution and a lie" (p. 143). Even Chillingworth makes reference to Enoch in his comment on "saintly men, who walk with God" (p. 122), echoing Genesis 5:24. Enoch, however, is a figure who transcends the bounds of orthodoxy, and to understand him better we must consult "the lore of the Rabbis" (p. 126), which occupies a place in the minister's study.

The pseudepigraphical *Book of Enoch,* based on Genesis 6:1-4, contains the prophet's visions of heaven, including the punishment of the fallen angels. It enjoyed popularity in Europe in several versions, may have influenced Milton, and appears to have been on Pico della Mirandola's reading list; in discussing man's potential to make himself "an angel, and a son of God," Pico writes, "metamorphoses were popular among the Jews. . . . For the more secret Hebrew theology at one time reshapes holy Enoch into an angel of divinity."[7] Romantic thought also inclined toward such metamorphoses, and the figure of Enoch naturally attracted its attention, as did those fallen angels with whom he is associated.[8]

New translations of *Enoch* were subjects of critical discussion in Hawthorne's day. In addition to striking chords of Neo-Platonism, they also raised questions about the nature of revelation and focused attention on archetypal readings of the world's religious literature. A compendium of Romantic uses of *Enoch's* themes is an 1833 review in *Fraser's Magazine,* which discusses literature and inspiration. After quoting Lycidas, it takes up Hawthorne's favorite symbol of revelation, the heart: "Home! sweet home! Look homeward!—there lies 'the crypt, the ark, the chest!' or whatever other 'receptacle' in which inspired writings shall be found. Home! Let each man place his hand on his heart, and find it there. There is the place of mystery, both of godliness and iniquity. Thence must come every revelation worthy of the name."[9] Certainly Dimmesdale's characteristic gesture of putting his hand to his heart indicates his withholding of his inner secret from the community; and after his confession of his pose as a mournful spirit, he does in fact display "what he bears on his own breast, his own red stigma," which "is no more than the type of what has seared his inmost heart!" (p. 255). This final revelation links him to Hester and Pearl, the living embodiment of the scarlet letter.

Pearl's role is parallel to that of Noah in *The Book of Enoch.* Like Noah, she is one of those strange children more suited to be among angels than among men (p. 90). In *Enoch,* Lamech laments, "I have begotten a son, unlike to other children." He worries that, "He is not human; but resembling the off-spring of the angels of heaven, is of a different nature from ours, being altogether unlike us. His eyes are bright as rays of the angels."[10] Hester raises similar questions about Pearl. "What is this being," she asks, "which I have brought into the world!" (p. 96). Though Enoch is able to foretell great things of Noah, however, Dimmesdale can only assure his daughter a human future by admission of his own passion in fathering her.

An admission of passion by the community's "angel" puts him in the company of those angels in *Enoch* who fell for "the daughters of men" (Genesis 6:2). Carl Jung's discussion of Byron's "Heaven and Earth," which treats the union of angelic and human, summarizes well some of the themes Hawthorne develops in the case of Dimmesdale: "The power of God is menaced by the seductions of passion; heaven is threatened with the second fall of angels. If we translate this projection back into the psychological sphere from whence it came, it would mean that the good and rational Power which rules the world with wise laws is threatened by the chaotic, primitive force of passion."[11] Throughout the romance, especially in the forest scene, passion is linked with lawless nature (p. 203). The *via media* of passion and reason is domestic. The home for which each of the characters strives ought to be a means of keeping passion in bounds. Pearl, because she is the embodiment of adulterous passion, in her final domestication signals the resolution of the tension between passion and law.

Unlike Enoch, Dimmesdale can neither translate nor see into the next world. Hester, who seems to hope for some reunion there with the minister, asks him, "Thou lookest far into eternity, with those bright dying eyes! Then tell me what thou seest?" He can only respond with the injunction to trust in God (p. 256). He is an Enoch who ends up in the graveyard, where he shares with Hester the single tombstone indicative of the community's acceptance of their bond in the stigma of the letter; however, this union is also found in the living letter, Pearl. For "their earthly lives and future destinies were conjoined" in Pearl, who is "at once the material union, and the spiritual idea, in whom they met, and were to dwell immortally together" (p. 207). Dimmesdale is brought to reveal his relationship to the organic world in Pearl, and his prophetic office points to the values of the human heart and the domestic circle.

Notes

[1] Nathaniel Hawthorne, *The Scarlet Letter,* ed. William Charvat, Vol. I. Centenary Edition of the Works of Nathaniel Hawthorne (Columbus: Ohio State University Press, 1962) p. 207. All subsequent references to this volume will appear in the text.

[2] Chillingworth's black arts are treated in my Hawthorne's "Chillingworth: Alchemist and Physiognomist," *TWA,* 72 (1984), 8-16.

[3] Allan I. Ludwig, *Graven Images: New England Stonecarving and It's Symbols* (Middletown: Wesleyan University Press, 1966), p. 216. In addition to the focus on the graveyard in *The Scarlet Letter,* see "Chippings with a Chisel" in *Twice-Told Tales.*

[4] For an analysis of how this distinction disappeared in Ficino, see Michael J. B. Allen, "The Absent Angel in Ficino's Philosophy," *Journal of the History of Ideas,* 36 (1975), 219-40. The backgrounds of Romantic thought show a distinct movement in this direction; angelic transformation is a favorite theme in its occult sources especially. See Auguste Viatte, *Les Sources Occultes du Romantisme* (Paris: H. Champion, 1928).

[5] "The Christian Triumph, Night IV," Vol. I. *The Complete Works,* ed. James Nichols (London, 1854), 534-42, p. 59. *Night Thoughts* originally appeared 1742-1745.

[6] *The New England Primer* (Hartford: Ira Webster, 1843).

[7] *On the Dignity of Man,* trans. Charles Glenn Wallis (Indianapolis: Bobbs-Merrill, 1965), pp. 5-6. For speculation on Milton's contact with *Enoch,* see Grant McColley, *"The Book of Enoch* and *Paradise Lost," Harvard Theological Review* 31 (1938), 21-39. Interest in *Enoch* was revived in 1773 by Bruce's discovery of an Ethiopic translation. Hawthorne would have known of *Enoch* from his readings of James Bruce's *Travels to Discover the Source of the Nile* in 1833, and Hiob Ludolf's *A New History of Ethiopia* in 1836. Neither, however, contains the substance of the book. See Marion L. Kesselring, "Hawthorne's Reading," *Bulletin of the New York Public Library,* 53 (1949), 174, 195.

[8] Consider Wordsworth's comment: "I used to brood over the stories of Enoch and Elijah, and almost to persuade myself that, whatever might become of others, I should be translated, in something of the same way, to heaven," in his notes in "Ode" Intimations of Immortality from Recollections of Early Childhood," *Complete Poetical Works* (London: Macmillan, 1913), p. 358.

[9] J. A. Heraud and William Maginn, *"The Book of Enoch," Fraser's Magazine* 8 (November, 1833), 513-14. The passage from Young previously cited is included in this article, p. 530. This review concerns itself with the Romantic use of the angel lore of *Enoch,* principally by Byron and Moore.

[10] *Fraser's,* p. 528. Though Dimmesdale's role as Enoch and angel is ironic, elsewhere in Hawthorne's work he suggests that the capacity to link man with the angels is a poetic gift. Hawthorne's ideal preacher seems to be Ernest in "The Great Stone Face." In his simple communion with nature Ernest seems to be a companion of the angels, and he fulfills the role ascribed to the poet who shows "the golden links of the great chain that intertwined them with an angelic kindred; he brought out the hidden traits of celestial birth that made them worthy of such kin" (*The Snow Image* Vol. XI, Centenary Edition (Columbus: Ohio State University Press, 1974) pp. 43-44. In creating such images for people, Dimmesdale can be seen as reminding them of their better nature; unlike Ernest, he is not in harmony with himself.

[11] *Symbols of Transformation,* 2nd ed. (Princeton: Princeton University Press, 1967), p. 112.

A PRELIMINARY STUDY OF THE MACROBENTHOS OF WAVE-SWEPT AND PROTECTED SITES ON THE LAKE MICHIGAN SHORELINE AT TOFT POINT NATURAL AREA, WISCONSIN

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Abstract

The near-shore summer macrobenthos community was sampled at protected and wave-swept sites in Lake Michigan at the Toft Point Natural Area, Door County, Wisconsin. A total of 85 genera were found. Differences in the species composition at the two sites can be related to the influence of water motion on feeding mechanisms. Wave-swept sites were dominated by typically lotic organisms which feed by a collector/scraper mechanism including heptageniid and tricorythid mayflies and hydropsychid caddisflies. Protected sites were dominated by corixid and gerrid hemipterans, amphipods, isopods and gastropods. Predaceous invertebrates were rare at the wave-swept sites but more abundant in the community at protected sites. The number of genera at protected sites increased gradually through the summer while at the wave-swept sites, the highest number occurred in early July.

Introduction

In contrast to the deep water benthos, the macroinvertebrate community of the shallow, wave swept shores of the Great Lakes has been examined by very few investigators. Krecker and Lancaster (1933) and Shelford and Boesel (1942) studied the beaches of the wave zone in western Lake Erie. Barton and Hynes (1978a) made an extensive summer survey of this community in Lakes Ontario, Huron, Superior and Erie. In Lake Michigan, Wiley and Mozley (1978) noted the occurrence of typically sedentary benthos in the pelagial, near-shore area but at depths of 6-9 m. Lauritsen and White (1981), using artificial substrate samplers at water depths > 0.5 m, compared the benthos of two locations in Lake Michigan; a wave-swept, but still somewhat protected, rocky shoal habitat in the northeast and a man-made, rocky riprap site in the southeast.

The purpose of this study was to make a preliminary examination of the macrobenthos community of shallow water sites (< 1 m) in Lake Michigan. Specifically, the community structure and feeding habits of macroinvertebrates in wave-exposed areas was compared with that in protected areas.

Site Description and Methods

The study was conducted at the Toft Point Natural Area on the northwest corner of Lake Michigan (Figure 1). Four sampling sites were selected, two on wave-swept shorelines (W1, W2) and two in protected areas (P1, P2). Sampling occurred four times in summer 1983: June 19, July 9, July 28-29, and August 19. On each sampling day, six to ten samples were collected within each site at depths from 0-1 m by thoroughly disturbing the sediment and rocks and then sweeping the area with a rectangular collecting net having a mesh

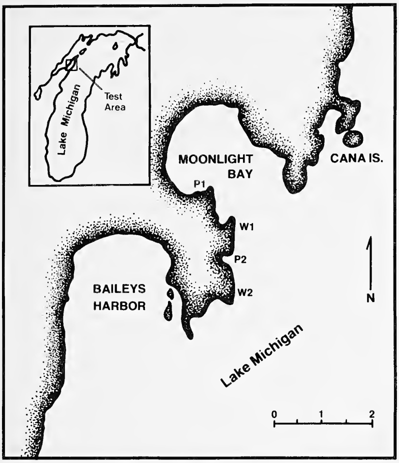

Fig. 1 Sampling sites on protected (P1, P2) and wave-swept (W1, W2) shores at Toft Point Natural Area.

size of 1 mm. Each sample was taken from an area of about $0.5 \cdot m^2$. Large rocks were carried to shore where the organisms were picked off. Collection of additional samples continued until no new taxa were found, usually after about two hours. Because of the mesh size of the net used in collecting, small organisms such as Hydracarina, Oligocheata and some Chironomidae are underrepresented in these collections. Chironomids, in contrast to most other organisms, were not identified to the generic level and therefore were not included when determining number of genera present at a site. Specimens were preserved in 70-80% ethanol. Most organisms were identified to the generic level using Hilsenhoff (1981) and Merritt and Cumming (1978) for insects and Pennak (1978) for all others.

At sites W1 and W2, the bottom has a shallow slope with the one meter depth located approximately 40 meters from the water's edge. The substrate here consists of Silurian Dolomite bedrock with scattered areas of boulders in the deeper areas and scattered areas of boulders, cobble, and gravel in the shallower areas. Tufts of vegetation were present near the very edge of the shoreline. Some patches of *Cladophora* were present on rocks in the shallower water.

Site P1 was located in a large protected bay. The substrate consists largely of sand and the dominant vegetation was *Scirpus* sp. Site P2 was located in a small bay, essentially a pocket in back of the wave-swept shore. The substrate was mostly particulate organic matter and the odor of hydrogen sulfide could sometimes be detected while collecting. The vegetation here consisted largely of *Carex* sp.

Results

The major taxa found at each site are listed in Table 1. A complete list can be obtained from the authors. A total of 85 genera, exclusive of Chironomidae, were found at the four sites; 47 were found on the wave-swept shores and 60 in the protected areas. In many cases only a single individual of a genus was found at a site. If these are excluded because of their rarity, 29 genera were found on the wave-swept shores and 29 genera in the protected areas.

Two insect orders, Ephemeroptera and Trichoptera, and the Crustacean orders, Isopoda and Amphipoda, were numerically dominant on the wave-swept shores. Colonies of Porifera and Bryozoa were also quite abundant. The latter organisms were not reported by Barton and Hynes (1978a) nor observed in a more recent study of the shallow-water epilithic invertebrate community of Georgian Bay (Barton and Carter 1982). Hemipterans were not found and Coleopterans were rare; adults were collected only near shore. Trichoptera larvae dominated by the family Hydropsychidae were always present at all depths but were often more abundant in deeper water. The dominance of Ephemeroptera

TABLE 1. Major taxa collected at each site and their trophic categories (based on Merritt and Cummins 1978). Abundances are the maximum obtained during any one sampling: A ≥ 10 individuals, M = 3-9 individuals, R ≤ 2 individuals and NC = none collected.

	Trophic Category	*W1*	*W2*	*P1*	*P2*
Odonata					
Coenagrionidae	Predators	NC	NC	M	A
Plecoptera					
Acroneuria	Predators	NC	A	NC	NC
Ephemeroptera					
Stenonema	Collectors/Scrapers	A	M	NC	NC
other Heptageniids	Collectors/Scrapers	M	M	NC	NC
Leptophlebia	Collectors	A	A	R	M
Baetis	Collectors/Scrapers	A	A	M	R
Caenis	Collectors/Scrapers	A	M	M	NC
Tricorythodes	Collectors	M	A	M	R
Trichoptera					
Symphitopsyche	Collectors	A	A	NC	NC
Cheumatopsyche	Collectors	A	M	NC	NC
Helicopsyche	Scrapers	M	M	NC	NC
Leptoceridae	Shredders/Collectors	NC	NC	M	NC
Coleoptera					
Dytiscidae	Predators	M	R	NC	R
Laccobius	Plant piercers	NC	M	M	NC
Tropisternus (larvae)	Predators	NC	NC	R	A
Gyrinidae	Predators	NC	R	M	R
Hemiptera					
Sigara	Collectors/Plant piercers	R	NC	A	A
Trichocorixa	Predators	NC	NC	A	A
Corisella	Predators	NC	NC	A	NC
Notonecta	Predators	NC	NC	M	A
Gerris	Predators	NC	NC	A	A
Belostoma	Predators	NC	NC	NC	A
Diptera					
Chironomidae	Collectors	A	A	A	A
Antocha	Collectors	NC	M	NC	R
Haplotaxida					
Naididae*	Collectors	M	M	R	NC
Hirudinea					
Erpobdellidae*	Scavengers/Predators	M	M	R	NC
Amphipoda					
*Gammarus**	Scavengers	A	A	A	NC
*Hyalella azteca**	Scavengers	NC	R	A	A
Isopoda					
*Asellus**	Scavengers	A	A	A	M
Gastropoda					
*Physa**	Scrapers	A	A	M	M
*Gyraulus**	Scrapers	R	R	M	A
*Lymnaea**	Scrapers	NC	M	A	A
Porifera*	Collectors	A	A	NC	NC
Bryozoa					
*Plumatella**	Collectors	A	A	NC	NC

* Placed into trophic categories based on the feeding habits described in Pennak (1978).

(Caenidae, Baetidae, Heptageneiidae and Leptophlebiidae) and Trichoptera (Hydropsychidae) was also mentioned by Barton and Hynes (1978a) for shallow waters in Lake Huron and Georgian Bay. These authors reported the stonefly, *Acroneuria* (Perlidae), here collected at site W2, (in late July and August) from Lake Superior, Lake Huron and Georgian Bay but not from Lakes Erie or Ontario.

The protected sites were dominated by Hemiptera, Amphipoda, and Gastropoda. Corixid nymphs and adults were often extremely abundant. Most organisms were present at all depths out to the edge of the emergent vegetation. Beyond the emergent vegetation, very few specimens were collected. The benthos of the two protected sites had many similarities, but there were also some notable differences as might be expected considering one had sand (P1) and the other an organic substrate (P2). Trichopteran larvae with portable cases (Leptoceridae and Lepidostomatidae) were present at P1 but not P2. Site P1 also had more Ephemeroptera nymphs. Site P1 had large numbers of the amphipods *Gammarus* sp. and *Hyalella azteca* in late summer, while at site P2 only the latter was found and then in large numbers only in late summer.

Feeding habits of the organisms are an important aspect of the aquatic invertebrate community. Cummins' (1973) designation of trophic categories for aquatic insects based on their feeding habits was used to classify the major taxa found in this study (Table 1). The categories of collector, scraper, and plant piercer were lumped together because specimens were not keyed to the species level which is often necessary to distinguish among categories. In some cases it was still necessary to partition a genus between two of the categories. Invertebrates other than insects were not treated by Cummins, therefore scavengers were included as an additional feeding category to accommodate them.

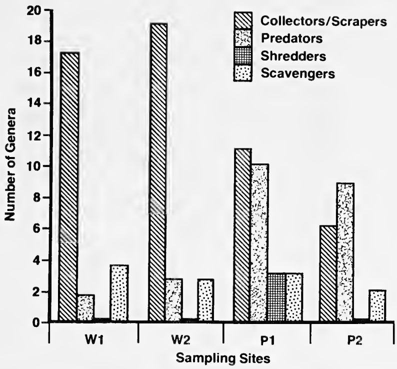

Fig. 2 Distribution of macrobenthos genera according to trophic categories (Cummins, 1973) at protected (P1, P2) and wave-swept (W1, W2) sampling sites at Toft Point Natural Area.

The importance of the various trophic categories in the community at each site is illustrated in Figure 2. Wave-swept sites are almost completely dominated both in diversity of genera and in abundance of individuals by collector/scrapers. These include the Ephemeroptera, *Heptagenia, Stenonema, Baetis* and *Tricorythodes,* and the Trichoptera, *Symphitopsyche* and *Cheumatopsyche.* Also observed in abundance were Porifera and Bryozoa, both of which utilize a collector-filterer type of feeding mode (Pennak, 1978). The only predator observed at the wave-swept sites was the stone fly, *Acroneuria.* Shredders were not found at either wave-swept site.

Both protected sites had fewer genera and lower abundance of collector/scrapers than the wave-swept sites. Predators, mostly Coenagrionidae (Odonata), Corixidae, Notonectidae, and Belastomatidae (Hemiptera), however, were much more abundant at protected sites. Shredders, represented primarily by Leptoceridae (Trichoptera) were observed at P1 but not P2.

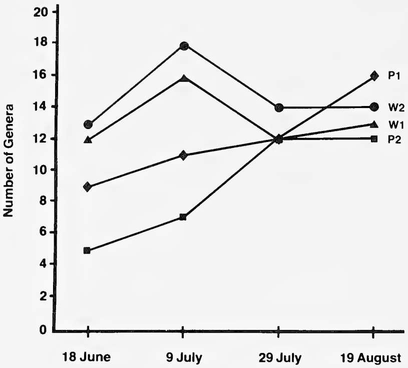

Fig. 3 Changes in number of genera of macrobenthos at protected (P1, P2) and wave-swept (W1, W2) sampling sites through the summer, 1982, Toft Point Natural Area.

Scavengers were present in similar numbers at all sites although P2, because of the absence of the amphipod, *Gammarus,* had the lowest abundance in this trophic category.

Significant changes in number of genera occurred in both types of habitats during the summer but at different times during the summer (Figure 3). At the wave-swept sites, the number of genera reached a maximum in early July. Genera which were rare or absent in mid-June but abundant or present in moderate numbers in early July were mostly collectors/scrapers including *Stenonema, Stenacron, Tricorythodes,* and a snail, *Physa.* Some prominent collector/scrapers such as *Leptophlebia, Caenis,* and *Cheumatopsyche* showed the opposite trend of large numbers of individuals in early summer but few or none in late summer. The predator *Acroneuria* was absent in early summer but abundant by late summer. Chironomids became more abundant through mid-summer followed by a decline at the last sampling.

At the protected sites, the number of genera continued to increase through the summer, reaching a peak at the last sampling. The increase was largely due to predators: adult *Gerris, Belostoma, Notonecta* and larval *Tropisternus.* These seasonal changes suggest fundamental differences in the trophic-dynamics of the communities at the two site types.

Discussion

Qualitative differences in the species composition at the two sites were evident. At the wave-swept sites, the macrobenthos consisted mainly of typically lotic species as noted also by Barton and Hynes (1978a). Adaptations for the lotic environment clearly are also advantageous in the wave-swept zone of large lakes. Lentic macrobenthos dominated at the protected sites.

It is clear that the benthos community structure is strongly influenced by water motion. The greater abundance and diversity of predators at protected sites suggests that most larger predators are better adapted for slow or standing waters. Indeed, in the wave-swept, marine rocky intertidal zone, it has been observed that predators often cannot forage effectively in highly exposed areas (Connell 1970, Dayton 1971). There is some evidence of mechanical limits to size in predators, and organisms in general, on wave-swept shores (Denny, et. al., 1985), but predators may be further hindered by a reduction in the efficiency of capture due to the turbulence.

The lack of predators in the wave-swept zone may have community-level ramifications. In the marine rocky intertidal, biological disturbance in the form of predation can control populations of dominant primary consumers, thus allowing less competitive species to exist (Paine 1966, Dayton 1971). Lubchenco (1978) and Sousa (1979) have shown that an intermediate level of disturbance, whether it be biological or physical (e.g., waves), tends to promote greatest diversity and abundance. The physical harshness of wave-swept sites on Lake Michigan, perhaps resulting in few predators, might explain the lack of rare species here as contrasted to the protected sites.

Several factors could influence the temporal distribution of macrobenthos at the wave-swept sites. The increase in number of genera from June to early July could still be a part of a recovery process after scouring by spring storms and late winter ice abrasion. Recolonization of these shallow areas could take place from less disturbed areas (Wiley and Mozley 1978) or deep water refuges (Barton and Hynes 1978b). The mayfly, *Leptophlebia,* is known to migrate from deep waters before emerging (Edmunds et al. 1976). Increased abundance of epilithic algae in early summer could also explain the appearance in early July of such groups as *Physa, Helicopsyche,* and some Ephemeroptera.

The disappearance of some genera at the wave-swept sites in late July may be due to the turbulent harshness of the environment. It could also be explained by completion of life cycles, e.g. the immature Ephemeroptera, *Caenis, Leptophlebia,* and *Stenonema,* were all absent by late July. Competition or predation could similarly contribute to the decline. Barton and Hynes (1978a) suggested an upwelling of cold hypolimnetic water into the littoral zone can limit the distribution of some Ephemeroptera and Trichoptera species. One possible example of limitation due to temperature fluctuations in this study is in the Odonata. While their complete absence from the wave-swept shores is not unusual, their low abundance and diversity in the protected areas (particularly the Anisoptera) may be due to cold water intrusions or severe temperature fluctuations. Another factor to explain the disappearance or absence of certain groups may be the lack of deep substrate due to shallow underlying bedrock (Barton and Hynes 1978c). This would reduce the success of, or preclude colonization by, species which have a requirement for deep substrate in some part of their life cycle. It is noteworthy in this sense that the increase in number of predators in the protected sites by late summer was mainly due to adult Hemipterans, most of which are swimming-skating forms that are less dependent on a soft bottom substrate.

Conclusions

Differences in species composition of the macrobenthos community of wave-swept and protected sites can be related to the important influence of water motion on trophic relationships in the community. Specific adaptations and feeding mechanisms produce a unique assemblage of typically lotic organisms in the wave-swept zone. Examples include taxa from the families Perlidae, Heptageniidae, Tricorythidae, Hydropsychidae, and Pleuroceridae. Almost completely absent in this community are predaceous invertebrates. Reduced water turbulence in the protected areas allows the development of an invertebrate community more like those typically found in small lakes or ponds. Temporal changes in the number of genera present show a peak in early July for the wave-swept community and a gradual increase throughout summer for the protected community.

In view of the lack of studies on the wave-swept zone of large inland lakes, particularly Lake Michigan, we encourage further research. There is a need for a yearlong study of the fauna; even Barton and Hynes (1978a) in their extensive study of the Canadian shores of the Great Lakes relied mainly on summer samples. Studies of disturbance caused by ice scouring and spring storms would be very interesting. These and others could provide valuable tests of theories concerning community organization developed in marine rocky intertidal communities.

Acknowledgment

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SEASONAL MOVEMENTS OF WHITE-TAILED DEER ON DECLINING HABITATS IN CENTRAL WISCONSIN

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Abstract

Land use changes may impact winter habitats of deer from a central Wisconsin grassland area. During 1979-82, we used radio-telemetry to document seasonal movements and ranges of 19 deer from this area and adjacent wooded uplands. Home ranges appeared smallest during the fawning period and summer and largest during fall. Deer that summered in the wooded uplands occupied the same respective areas year round, but those from the open grassland area moved to the uplands mainly in early to mid-October and returned during mid-February through March. Deer in the study area probably will be affected negatively if their common winter (upland woods) habitat continues to be diminished.

INTRODUCTION

The 200-km² Buena Vista Marsh (BVM) is a unique grassland area in central Wisconsin that harbors white-tailed deer (*Odocoileus virginianus*) from late spring through fall. Wintering areas of deer from BVM are unknown; woodlots in surrounding uplands may serve as winter cover but these are being replaced by irrigated croplands (Butler 1978). The objective of this study was to obtain baseline data on seasonal movements and ranges of radio-marked deer from BVM and adjacent uplands. Habitat use by these deer was reported earlier (Murphy et al. 1985).

We are indebted to all landowners for their cooperation. M. Gratson and O. Rongstad offered helpful suggestions during the study. This work was funded by the University of Wisconsin Cooperative Research Projects Consortium.

STUDY AREA AND METHODS

The 327-km² study area includes 137-km² of the drained BVM in southwestern Portage County, Wisconsin, and 190 km² of adjacent uplands. The study area in BVM consists of 38% grassland and grass-shrub types (Kentucky bluegrass (*Poa pratensis*), quackgrass (*Agropyron repens*), goldenrod (*Solidago* spp.), willow (*Salix* spp.), and shrub-stage trembling aspen (*Populus tremuloides*), 31% open pasture, 23% cropland (corn, cash crops, and hay), and 8% small (15-60 ha) woodlots (aspen). The uplands consist of 42% woodlots and 10% shrub (both dominated by mixed oak (*Quercus* spp.), jackpine (*Pinus banksiana*), and aspen), 35%

cropland (corn, cash crops, and hay), and 13% idle fields and pasture. Soils are primarily flat sands from glacial outwash. Mean annual precipitation is 75 cm, including 110 cm of snow; mean annual temperature is 6°C with extremes of −42° and 42°C.

Deer were captured and marked throughout the study area and were radio-located almost daily as described in Murphy et al. (1985); multiple daily locations were collected during the deer hunting season. For movement data, we recognized 6 periods: spring (16 Feb-15 May), fawning (16 May-15 Jul), summer (16 Jul-15 Sep), fall (16 Sep-21 Nov), gun deer season (22-30 Nov), and winter (1 Dec-15 Feb).

The most frequented parts of an animal's home range have been termed "core areas" (CAs) (Ewer 1968:65). Isopleths that contained 67% of a season's radio-locations and that were defined by harmonic mean activity centers (Dixon and Chapman 1980) were used to define CAs in this study. Bucks that moved from their summer CAs during fall and that were shot during gun season were considered to be on their winter CAs based on our knowledge of movements of does that survived gun season. CA size for deer that used 2 CAs in a season was considered the sum of the areas.

Results and Discussion

We captured 29 deer during June 1979-February 1981; 10 were ear-tagged, and 19 were radio-collared and followed 2-30 months ($\bar{x} \pm SD = 8.5 \pm 7.0$) each during November 1979-November 1982. About 2,500 radiolocations were collected. Movement data were supported by observations of unmarked deer.

Deer that used BVM during summer (hereafter, "marsh deer") had separate winter CAs in the uplands that averaged 10.2 km (SD = 5.8) from their summer CAs (Fig. 1). Deer that used uplands as summer habitat (hereafter, "woods deer") maintained year round CAs.

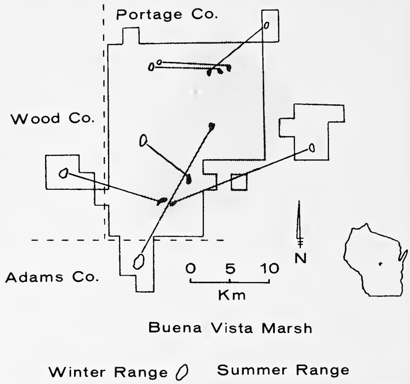

Fig. 1. Winter and summer core areas of 7 deer from the Buena Vista Marsh, Wisconsin, 1980-82.

Marsh deer moved to uplands mainly in early to mid-October (Table 1), perhaps in response to the 1st frosts. Oak mast probably attracted deer to uplands (Murphy et al. 1985). In spring, deer returned to BVM when successive daily temperatures reached 8-15° C, during mid-February through March following a mild winter (average Feb. and Mar. snow depths in 1981 were 8.0 and 0.0 cm, compared to 22.4 and 19.4 cm for 1961-77), and during April following a severe winter (average Feb. and Mar. snow depths in 1982 were 47.6 and 20.8 cm) (Table 1). Similarly, Hamerstrom and Blake (1939) reported that central Wisconsin deer move from their wintering areas during March and April, and move earlier after short, mild winters. In our study, spring movements appeared to coincide with the availability of green forage in open areas (Murphy et al. 1985).

Marsh deer winter CAs were in mixed upland woods mainly west of BVM (Fig. 1) and overlapped year round CAs of woods deer. Trail counts conducted on the study area after fresh snowfall (winter 1981-82) further suggest that deer winter almost exclusively in wooded uplands (D. Groebner, unpubl.). Irrigated cropland probably will

TABLE 1. Movement of radio-collared white-tailed deer to and from summer CAs (core areas) on the Buena Vista Marsh, Portage County, Wisconsin, 1980-82. S = Summer CA; W = Winter CA.

Deer no.	*Distance*[a] *(km)*	*Movement chronology*
Yearling females		
02	6.0	S-------WSW--SW-----------S--------W------[b]
22	16.5	S-- --W?-[c]
23	20.0	S-------------W-------S----------------W------------S-------------[d]
Adult females		
26	7.1	S-------WSWSWSW------SW-SWS---------- W-[b]
27	7.1	S-----W?-[c]
Yearling males		
12	4.8	S--------W----[b]
20	9.7	S--------W-----[b]
Months		J A S O N D J F M A-----S O N D J F M A-----S O N

[a] Distance between summer and winter CAs.
[b] Shot during deer hunting season.
[c] Killed on presumed winter CA by vehicle collision.
[d] Shot during deer season between winter and summer CAs.

continue to replace these upland habitats (Butler 1978). Deer make little use of irrigated cropland, probably because of inherent farming practices (Murphy et al. 1985). Thus, this change in land use may inimically impact deer.

Home Range Characteristics

Individual deer CA sizes varied considerably (Table 2), from 4 ha for an adult doe in upland woods during winter to 1,932 ha for a yearling buck in open grassland during fall. However, for statistical analyses, the data set was too fragmented by sex, age, habitat ("marsh" vs. "woods" deer), and season variables. Therefore, CA data and related movements are summarized descriptively.

Spring CAs appeared intermediate in size compared to other seasons (Table 2). Deer made frequent forays (0.7-2.9 km) to rye and cornfields (Murphy et al. 1985). During fawning period and summer, deer appeared to use relatively small areas (Table 2), probably because habitat needs were well met during these periods and, except for agricultural activity, deer were free from disturbance. Relatively small home range size during fawning-summer has been reported by others (Sparrowe and Springer 1970, Nelson and Mech 1981). Adult does appeared to use smaller areas than other deer during the fawning period, but they increased their movements during summer as their fawns became more mobile and social intolerance toward other deer presumably decreased (Ozoga et al. 1982).

Increased movements during early fall appeared to be food-related while those in late fall were associated with the rut. For exam-

TABLE 2. Seasonal core area sizes (ha, $\bar{x} \pm SD$) for radio-collared deer from the Buena Vista Marsh (marsh deer) and adjacent uplands (woods deer), Portage County, Wisconsin, 1980-81.

Sex and age classes[a]	*Season*					
	Spring	*Fawning season*	*Summer*	*Fall*	*Hunting season*	*Winter*
Marsh deer						
Yearling males	120 ± 103	94 ± 84	69 ± 22	881 ± 702	170	
(N deer, observations)	(4,92)	(4,122)	(4,141)	(4,197)	(1,17)	
Yearling females	116	37 ± 38	20 ± 22	152 ± 115	485 ± 535	149 ± 161
(N deer, observations)	(1,21)	(3,85)	(3,91)	(3,145)	(2,42)	(2,56)
Adult females	233 ± 98	18 ± 3	84 ± 98	134	89	4
(N deer, observations)	(3,67)	(2,54)	(2,70)	(1,41)	(1,21)	(1,25)
Woods deer						
Fawn female[b]				5	14	9
(N observations)				(36)	(17)	(22)
Yearling males	62 ± 14	232[c]	56	53		
(N deer, observations)	(3,80)	(1,24)	(1,25)	(1,26)		
Yearling females	56 ± 1	61	12	27	41	
(N deer, observations)	(2,62)	(1,25)	(1,25)	(1,31)	(1,21)	
Adult male	310	56	51	270	47	
(N observations)	(35)	(27)	(35)	(40)	(10)	

[a] Age class based on age at fawning season (e.g., "yearlings" are about 0.8 and 1.0 years old during spring and fawning season, respectively).

[b] Data were collected during fall-winter, 1979-80.

[c] Dispersed during fawning season and did not establish a home range until summer.

ple, a yearling buck moved (28 Sep and 6 Oct) 4.0 km from his CA at BVM to a 65-ha cornfield where he remained 3-4 days. Two other yearling bucks wandered extensively over 35-km² areas at BVM during late fall. Both bucks and does at BVM made irregular movements during rut, but those of bucks seemed more frequent and extensive (Table 2), as Downing and McGinnes (1975) noted for white-tails in Virginia.

Deer response to hunter pressure during gun season varied. One adult and 1 yearling buck reduced their activity to within small, heavily wooded CAs (Table 2) and survived 5 and 7 days, respectively, of the 9-day gun season. Four yearling bucks responded to drives by crossing open areas and were shot on the 1st day of gun season. Does and fawns exhibited strong home range fidelity; hunters drove them 0.5-9.0 km from their CAs, but they returned at night.

During winter, deer made regular feeding trips (0.4-1.0 km) to hay and to cornfields. The winters of 1979-80 and 1980-81 were mild (average Dec., Jan., and Feb. snow depths were 1.5, 3.8, and 7.9 cm compared to the 1961-77 averages 9.1, 24.3, and 22.4 cm) and deer probably would have smaller CAs (Table 2) in more severe winters.

SUMMARY AND CONCLUSIONS

We observed 2 behavioral patterns on the study area: woods deer fulfill their needs on year round CAs in uplands adjacent to BVM; marsh deer fulfill their food and cover needs at BVM during spring through fall, but move to surrounding uplands to fulfill these needs during winter. Seasonal movements of marsh deer suggest these deer may be considered migratory, while woods deer appear sedentary.

Sizes of areas used by deer appeared

largest in fall and smallest during the fawning period and summer. Seasonal changes in CA size and movements seemed related to factors documented in other studies.

Deer that move from BVM supplement fall populations, and thus the hunting harvest, of deer in adjacent uplands. Similarly, movement of deer from some refuges is important to the deer harvest in surrounding areas (Hawkins et al. 1971, Kammermeyer and Marchinton 1976). We predict that deer harvests at BVM and in surrounding uplands will decrease if winter (upland woods) habitat continues to be removed and trends in local farming practices remain unchanged.

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NEW DISTRIBUTIONAL RECORDS FOR WISCONSIN AMPHIBIANS AND REPTILES

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Abstract

Twenty distributional records are provided for thirteen species of Wisconsin amphibians and reptiles. Most represent new county records.

INTRODUCTION

The geographic distribution of the Wisconsin herpetofauna was summarized most recently by Vogt (1981), with additional records provided by Cochran (1982 a,b,c, 1983 a,b), Cochran and Hodgson (1985, 1986), Cochran et al. (in press), and Hodgson and Cochran (1986). The purpose of this paper is to provide new distributional information for several Wisconsin amphibian and reptile species. Not only do these records fill distributional hiatuses, but they serve to document the existence of species at particular points in time and space. Such information can be used as baseline data to compare with future observations.

The following format has been used to report each new record: scientific name, common name (after Collins et al. 1982), locality, date of collection, collector(s), place of deposition and catalog number (where appropriate), and comments. Unless otherwise specified, each specimen described below represents the first published record for its respective county, based on Vogt (1981) and additional references cited in Cochran (1982d). All specimens except the *Crotalus* were verified by one or both authors.

CAUDATA

Ambystoma laterale (Blue-spotted salamander). (1) Sawyer County: one found beneath a piece of bark in woods on northeast side of confluence of Mosquito Brook with Namekagon River (T41N,R9W,S12). 22 Sep 1983. Cochran, Lyons. Total length: 106 mm, snout-vent length: 57 mm. Erythrocyte area (Austin and Bogart 1982): $\bar{X}=728.9$ μm^2, $N=10$, range $=589.0$-809.9 μm^2. Described as uncommon by Briggs and Young (1976) for nearby Pigeon Lake region in Bayfield Co. (2) Burnett Co: Five individuals found beneath logs near wooded vernal pool at wayside park along St. Croix River on south side of Hwy. 70 (T38N, R20W,S24). 25 May 1984. Cochran, Lyons. Photograph in University of Wisconsin-Madison Zoology Museum (UWZ) collection (Accession Number 84-147). (3) Marinette Co: two individuals found beneath a log at Bear Point Landing on the Menominee River along Hwy 180; one was preserved. 24 Jul 1986. Cochran, J. A. Cochran. UWZ H22633.

Ambystoma tremblayi (Tremblay's salamander). Vilas Co: One beneath a rock at edge of driveway at University of Wisconsin Trout Lake Station (T41N,R7E,S19). 1 Oct

1983. Cochran, J. Freedman, Lyons. Photographed (UWZ Accession Number 84-147). Total length: 13.5 cm; snout-vent length: 73 cm. Erythrocyte area (Austin and Bogart 1982): $\bar{X}=1025.9\ \mu m^2$, N = 10, range 917.9-1119.2 μm^2. Diffuse blue coloring along sides. Reported by Vogt (1981) for adjacent Oneida and Price Counties. Lyons observed several additional specimens in spring 1984, in a small vernal pool next to the Trout Lake Station Laboratory. The only specimen captured had a small fingernail clam attached to one toe (see Davis and Gilhen 1982).

Hemidactylium scutatum (Four-toed salamander). (1) Vilas Co: Found beneath a log near wooded pool adjacent to Trout Lake Station Laboratory. (T41N,R7E,S19). 1 Oct 1983. J. Freedman, Cochran, and J. D. Lyons. Vogt (1981) listed an unconfirmed record for adjacent Forest Co, and Robinson and Werner (1975) reported its presence in Michigan's Upper Peninsula. (2) Portage Co: In woods on south side of Blackberry Hill Road (T23N,R7E,S19). 22 Jun 1985. Cochran, with J. A. Cochran, A. G. Cochran, D. Watson. Preserved in St. Norbert College Biology Department reference collection. Previously reported from the opposite end of Portage Co by Vogt (1981). This record is included because of the relative paucity of records for this elusive species and because it corresponds to what is apparently atypical habitat (upland forest, no boggy habitat in the vicinity). Other species collected include a single *Bufo americanus* and numerous *Plethodon cinereus.*

Necturus maculosus (Mudpuppy). (1) Richland Co: Wisconsin River (T8M,R1E, S5), 100 m upstream of public boat landing on north side of river. 13 Apr 1985. David J. Heath. UWZ H22610. (2) Crawford Co: Caught in hoopnet in Wisconsin River just downstream from Hwy 18/35 bridge (T6N, R6W,S14). 15 Apr 1985. Lyons, S. Landon, T. Pellett.

Anura

Pseudacris triseriata (Chorus frog). Sawyer Co: One adult and several tadpoles preserved from Airport Road between Hwy 63 and Namekagon River (T41N,R9W,S23). 23 May 1984. Cochran, Lyons. UWZ H22578. This species was heard calling from several wetlands along Airport Road, with *Hyla crucifer, Rana pipiens,* and *R. sylvatica* also present. Described as common by Briggs and Young (1976) for the nearby Pigeon Lake region in Bayfield Co.

Testudines

Chelydra serpentina (Common snapping turtle). (1) Green Co: Small adult in Sugar River, just upstream from Ten Eyke Road Bridge near Brodhead (T2N,R9E,S26/35). 16 Jun 1983. Cochran, Lyons, F. J. Rahel. (2) Trempeleau Co: juvenile recently killed on Hwy 54/35 just south of Trempeleau River. 30 Apr 1985. Cochran. UWZ H22634. Substantiates record in Vogt (1981) not based on examined specimen.

Clemmys insculpta (Wood turtle). Sawyer Co: Confluence of Mosquito Brook with the Namekagon River (T41N,R9W,S12). 23 May 1984. Lyons, Cochran. Photographed (UWZ Accession Number 84-147). Included on the list of state threatened species. Previously reported from the northwest corner of Sawyer Co by Vogt (1981).

Emydoidea blandingii (Blanding's turtle). Jackson Co: Recently killed on Hwy 54 about 1.5 km. east of Kirch Road. 30 April 1986. Cochran. UWZ H22635. Substantiates record in Vogt (1981) not based on examined specimen.

Trionyx muticus (Smooth softshell turtle). Grant County: Collected in fish seine from main channel of Mississippi River, Pool 11, River Mile 605. 6 May 1946. J. Greenbank. Originally included with a preserved sample of fishes (MR 132), but now recatalogued separately as UWZ H22581. First published record from Pool 11 (Vogt 1981, Williams and Christiansen 1981).

Trionyx spiniferus (Spiny softshell turtle). Pierce Co: (1) Collected in fish seine from Mississippi River, Pool 4, center of back channel approximately 0.4 km below Goose Lake outlet. 5 Sep 1947. Miron and Monson. Originally included with a preserved sample of fishes (MR 228), but now recatalogued separately as UWZ H22579. (2) Collected in fish seine from Mississippi River, Pool 3, Wisconsin shore of main channel near Diamond Bluff. 26 Sep 1947. Miron and Monson. Originally included with a preserved sample of fishes (MR 238), but now recatalogued separately as UWZ H22580.

Serpentes

Heterodon platyrhinos (Eastern hognose snake). (1) Wood County: Found freshly killed at ca 2300 h on Hwy 54 about ¼ km south of G.B. & W railroads tracks. 6 Aug 1980. Cochran. Many small anurans were observed hopping on the road in the same general area after the passage of scattered thunderstorms. Although Vogt (1981) stated that this snake is most abundant in Wisconsin's central "sand counties," he included no record for Wood Co. (2) Jackson Co: adult recently killed on Hwy 54, just west of north turnoff for Co Road K. 30 Apr 1986. Cochran. UWZ H22636. Substantiates records in Vogt (1981) not based on examined specimens.

Storeria occipitomaculata (Redbelly snake). Sawyer Co: Federal campsite on Namekagon River just downstream from Hwy 63 crossing (T42N,R8W,S31). 20 Sep 1983. Cochran, Lyons. Photographed (UWZ Accession Number 84-147). Described as common by Briggs and Young (1976) for nearby Pigeon Lake region in adjacent Bayfield Co.

Crotalus horridus (Timber rattlesnake). On 24 Jul 1983, a girl was bitten by a timber rattlesnake just south of Somerset, St. Croix Co (Keyler 1983). St. Croix Co was not included by Vogt (1981) within the current range of the timber rattlesnake on the basis of recent records, but it was included within the historical range by Schorger (1967-68).

Acknowledgments

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FOREST FLOOR BIOMASS AND NUTRIENTS IN RED MAPLE (*Acer rubrum* L.) STANDS OF WISCONSIN AND MICHIGAN

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Abstract

The forest floors of 60 even-aged red maple stands were sampled in northern Wisconsin and Michigan. Dry weights and nutrient contents were determined for the Oi + Oe and Oa horizons, as well as for the total forest floor. All data were arranged into three soil productivity groups based on site index (18.9, 17.6 and 14.9m). The greatest forest floor dry weight and nutrient contents were associated with the highest soil productivity group. The lowest group, which consisted of the dry, sandy outwash sites, had the smallest forest floor dry weights and nutrient storage. The bulk of the dry weight and nutrient content of the forest floor was in the Oa horizon.

Introduction

Red maple (*Acer rubrum* L.) is a tree species of interest to many foresters in the Lake States. Crow and Erdmann (1983) estimated that red maple is now an important component on more than 400,000 ha in the Lake States. Red maple is a moderately tolerant species, a prolific sprouter and seed producer, and a fast grower. All of these characteristics have allowed it to become a strong competitor for the growing space vacated by American elms (*Ulmus americana* L.) killed by Dutch elm disease. Red maple occurs on a variety of sites ranging from dry to wet, but is most abundant in dry-mesic sites (Curtis 1959).

The forest floor represents an important component of a forest ecosystem. It provides a niche for a variety of microflora and fauna, a seedbed for forest vegetation, and nutrients that are continuously made available for plant growth through mineralization processes (Pritchett, 1979). In addition, the forest floor stores water and reduces runoff. Early forest floor studies in this country focused on classification for inventory purposes (Romell and Heiberg 1931, Heiberg and Chandler 1941), while more recent investigations have dealt with such topics as nutrient release through decomposition (Aber and Melillo 1980). The forest floor has recently been recommended for classifying forest ecosystems (Snyder and Pilgrim 1985). There is still a need for forest floor information for various timber types in the Lake States. As soil surveys increase in scope and as forest management intensifies to include practices such as drainage, fertilization, and prescribed fire, the need for additional information on soil-site classification and nutrient cycling in forest ecosystems will become more pressing.

The information presented here is part of a larger, regional study investigating soil-site relationships of red maple. The specific objective is to report forest floor dry weight, depth, and macro- and micronutrient contents associated with red maple stands growing on three soil productivity groups in northern Wisconsin and Michigan.

Methods

Sixty even-aged red maple stands were located throughout northern Wisconsin and Michigan (Table 1). The stands were all fully-stocked, and originated from seeds

Table 1. Mean stand conditions for three soil productivity groups in northern Wisconsin and Michigan[1]

Soil Productivity Class	No. Stands	Stand Age (Yrs)	Site Index (m)	Basal Area (m^2/ha)	Stand Biomass (t/ha)	Mean Annual Biomass Increment (t/ha/yr)
I	22	62a	18.9a	31.4a	222a	3.6a
II	18	66a	17.6b	31.4a	220a	3.4a
III	20	67a	14.9c	28.4a	184b	2.8b

[1] Means within a column followed by the same letter are not significantly different at the 0.05 level.

rather than stump sprouting. They occur on a variety of parent materials, including lacustrine sediments, glacial till, and glacial outwash. The soil moisture regimes ranged from dry mesic to mesic.

Within each stand two 1,000 m^2 plots were established. Site index was obtained from stem analysis of at least two dominant or co-dominant trees per plot. Biomass was computed from dbh measurements using equations developed by Crow (1983). In each stand a soil pit was dug to a depth of 2 m and described by horizons. A 0.25 m^2 forest floor sample was collected near each pit, separated into Oi + Oe and Oa horizons, and returned to the lab for analysis.

In the lab the Oi + Oe samples were oven-dried at 65°C, then ground in a Wiley mill to pass a 1 mm sieve. The Oa samples were dried and gently passed through a 2 mm sieve; organic material not passing through the sieve was ground in a Wiley mill and remixed with the rest of each sample. All forest floor samples were digested in concentrated nitric and perchloric acid, and total P, K, Ca, Mg, S, B, Mn, Zn, Cu, and Fe were

Table 2. Mean dry weight, nutrient contents, and depth for the total forest floor (Oi + Oe + Oa horizons) for three soil productivity groups[1]

Productivity Group

variable	I $\bar{x}$	I SD	II $\bar{x}$	II SD	III $\bar{x}$	III SD
	kg ha^{-1}					
Dry wt.	45,752 a	15,858	44,636 a	18,163	29,182 b	9,159
N	565 a	314	458 b	210	294 c	126
P	37 a	12	31 b	11	21 c	7
K	38 a	11	30 b	11	20 c	7
Ca	210 a	105	164 b	65	100 c	37
Mg	38 a	19	33 a	20	18 b	10
S	54 a	28	46 a	24	29 b	13
Zn	3.0a	1.6	2.4b	1.7	1.2c	0.6
B	0.6a	0.2	0.5a	0.2	0.3b	0.1
Mn	40.1a	73.2	23.6a	18.5	21.9a	13.7
Fe	162.8a	114.7	159.0a	149.6	67.1b	34.7
Cu	0.8a	0.5	0.6b	0.3	0.4c	0.2
depth (cm)	9.2a	3.6	9.5a	2.9	7.5b	2.4

[1] Means, within a row, followed by the same letter are not significantly different at the 0.05 level.

determined using a Model 34000 ARL plasma emission spectrophotometer at the University of Wisconsin-Madison. Total N was determined on ground subsamples at the University of Wisconsin-Stevens Point using the semi-micro Kjeldahl procedure.

During the field sampling phase of the study, site productivity differences associated with soil parent material and drainage class became apparent. Two measures of productivity, site index and mean annual biomass increment, were subjected to cluster analysis using Ward's hierarchical method (Ward 1963). Three distinct groups were produced, and forest floor dry weights and depths were stratified by group and subjected to an analysis of variance followed by mean separation using Duncan's Multiple Range Test at the 0.05 level. All statistical analyses were performed using SPSS on the Burroughs B6900 mainframe computer at the University of Wisconsin-Stevens Point.

Results and Discussion

The three soil productivity groups sampled differred primarily in soil parent material and drainage class. The highest group had a mean site index of 18.9 m, and consisted of the lacustrine soils and till soils that were moderately well-drained. The intermediate group had a mean site index of 17.6 m and consisted of other glacial till soils and the wet outwash soils. The lowest productivity group had a mean site index of 14.9 m and consisted of the dry glacial outwash sites.

In general, the highest soil productivity group contained the largest forest floor biomass with the greatest amount of associated nutrient storage (Table 2). For example, soil productivity group I had an average forest floor dry weight of 45,752 kg/ha. This was not different from the 44,636 kg/ha associated with group II, but was significantly higher than the 29,182 kg/ha found with the group III sites. Significant differences were also found with N,P,K,Ca,Mg,S,Zn,B, Fe, and Cu (Table 2). The same trend was exhibited with Mn, however, the differences were not significant.

The greatest dry weight and associated nutrient storage was found in the Oa horizon (Tables 3,4). This was due in part to the associated mineral matter which forms an integral part of the Oa horizon. The large amounts of Fe found in the Oa are most likely associated with this mineral soil. The Oa horizon comprised 69%, 75%, and 70% of the total forest floor dry weight for soil productivity groups I, II, and III respectively. Although the Oa horizon on group II sites had a slightly higher dry weight than on group I sites, the group I sites had higher nutrient contents, indicating a higher nutrient concentration in the group I Oa horizons.

The association between low (moist) drainage conditions and higher forest floor dry weights and nutrient contents has been documented in the literature (Mader et al. 1977, Reiners and Reiners 1970, Perala and Alban 1982). In this study the group I and II sites were noticeably wetter than the dry, sandy outwash group III sites, which partially explains the larger forest floor dry weights and nutrient contents on those sites. In addition, above-ground biomass production and litterfall have been observed to be lower on sandy, infertile sites in the Lake States (Perala and Alban 1982).

Conclusion

This study showed that the higher quality red maple sites investigated had greater forest floor dry weights with greater associated macro- and micronutrients, and occurred on mesic to moist sites. The poorest quality sites, which occurred on the dry outwash sands, had forest floors that were significantly lower in dry weight and nutrient content. Management practices that are likely to impact the forest floor (i.e. site preparation, prescribed burning) should be practiced with more care on the group III

TABLE 3. Mean dry weight and nutrient contents for the Oi + Oe forest floor horizons for three soil productivity groups[1]

	Productivity Group					
	I		II		III	
variable	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
	kg/ha					
Dry wt.	14,286 a	8,670	11,233 b	5,783	8,666 c	4,441
N	218 a	155	179 b	104	131 c	63
P	13 a	7	10 a	5	9 a	4
K	13 a	8	11 a	7	9 a	4
Ca	111 a	54	92 a	33	70 b	29
Mg	11 a	7	9 ab	4	7 b	3
S	20 a	15	16 a	11	12 a	6
Zn	1.0a	0.7	0.7ab	0.4	0.4b	0.3
B	0.2a	0.1	0.2ab	0.1	0.1b	0.1
Mn	10.9a	4.9	12.0a	7.5	13.3a	6.1
Fe	14.2a	10.1	12.8ab	8.6	7.2b	4.8
Cu	0.2a	0.1	0.1ab	0.1	0.1b	0.1

[1] Means, within a row, followed by the same letter are not significantly different at the 0.05 level.

TABLE 4. Mean dry weight and nutrient contents for the Oa forest floor horizons for three soil productivity groups[1]

	Productivity Group					
	I		II		III	
variable	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
	$kg\ ha^{-1}$					
Dry wt.	31,466 ab	9,516	33,402 b	16,472	20,516 a	6,482
N	347 a	188	279 ab	158	163 b	83
P	25 a	11	20 ab	10	13 b	4
K	25 a	12	19 ab	8	11 b	5
Ca	99 a	75	72 ab	46	30 b	14
Mg	27 a	18	24 ab	20	11 b	7
S	34 a	18	29 ab	20	17 b	8
Zn	2.1a	1.3	1.7ab	1.5	0.8b	0.4
B	0.3a	0.1	0.3a	0.1	0.2b	0.1
Mn	29.2a	73.5	11.5a	17.8	8.7a	11.5
Fe	148.7a	115.3	146.2a	151.5	60.0b	32.7
Cu	0.6a	0.4	0.5ab	0.3	0.3b	0.2

[1] Means, within a row, followed by the same letter are not significantly different at the 0.05 level.

sites and nutrient conservation measures should be followed (Bengston 1981).

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From the Editor

After completing work on Volume 74, 1986, Philip and Kathryn Whitford resigned as editors of *Transactions.* Their dedicated work for the journal, sometimes under difficult circumstances and without adequate support staff, is greatly appreciated. As the new editor I wish to acknowledge their contribution, and on behalf of all associated with the journal, to express our sincere thanks to the Whitfords for their excellent work. My hope is to maintain the standards of judgment, breadth of view, and quality of product so long evident under the Whitfords' editorship.

Readers will note only modest changes in the 1987 volume of the journal. There are a few technical changes in this issue, but the addition of assistant editors and a production editor has already meant an increase in the services we have been able to provide to authors. And recent changes at the Academy office plus the support that naturally comes from being associated with a university campus, have increased the resources available to the journal. No dramatic changes are anticipated though I do plan to include more material from arts and letters. The next volume will have a poetry section, and consideration is being given to a photographic essay, a series of profiles of Wisconsinites, an interview, and original ink drawings or woodcuts. It is my hope that *Transactions* will reflect the diverse interests and activities of the members of the Wisconsin Academy as well as continue to serve as a place to present original work by Wisconsin writers or about Wisconsin.

Three aspects of this volume of *Transactions* should be noted. The first is the inclusion of the Bruce Taylor poem, which gives some indication of things to come. Bruce has agreed to serve as poetry editor for the 1988 volume. The second is the unusually long and detailed lead article entitled "Wisconsin Death March." In this article Professor Clifton meticulously reconstructs the story of an episode in American and Wisconsin history that injected suspicion and bitterness into the relationship between the Chippewa Indians and various agencies of the government. The article serves as an ideal background against which to place the current arguments over the Chippewa's exercise of rights they reserved by treaty. The 1987 volume concludes with another article in a series that began a number of years ago. Botanists are studying the flora of Wisconsin, and *Transactions* was selected as the journal to publish the occasional reports. When the study is completed, this journal will be the major source of information for anyone studying the flora of Wisconsin. We are pleased to continue our participation in this project with the publication of the report on Euphorbiaceae—The Spurge Family.

All of us at *Transactions* hope that you enjoy this volume and that you will consider submitting ideas or completed works for possible publication.

Carl N. Haywood

Wisconsin Death March: Explaining the Extremes in Old Northwest Indian Removal[1]

James A. Clifton

Throughout the fall of 1850, four officials of Zachary Taylor's administration conspired to lure the Lake Superior Chippewa Indians away from their lands in Northern Wisconsin and Michigan's Upper Peninsula.[2] Two of these officials, Secretary of the Interior Thomas Ewing and Commissioner of Indian Affairs Orlando Brown, provided the initial approval for the plan, but they did not remain in office long enough to witness its disastrous results. The others, Minnesota Territory's governor, Alexander Ramsey, and Sub-Agent John Watrous, were directly involved as prime movers from start to end. By moving the place for the annual annuity payments to a new temporary sub-agency at Sandy Lake on the east bank of the upper Mississippi and by stalling the delivery of annuity goods and money, they planned to trap the Chippewa by winter weather, thus forcing them to remain at this remote, isolated location.

This scheme, kept secret from both local Americans and the Chippewa, was designed to break the tenacious resistance of these Indians, who had rebuffed earlier efforts to persuade them to resettle in northwestern Minnesota. The stratagem failed. It succeeded only in reinforcing the opposition of the Chippewa to relocation even though it had killed large numbers of them: of the some three thousand (mostly adult males) who gathered at Sandy Lake in early October, some four hundred died before the survivors could make their way back to their homes by the following January.[3]

This incident was demonstrably atypical of the experiences of the two dozen other Indian populations in the Old Northwest who were subject to the Indian Removal policy between 1825 and the early 1850s.[4] On the contrary, judged by the degree of physiological stress and the casualty rate suffered during the relocation process, the Lake Superior Chippewa case represents an extreme. As such, it deserves special attention, since it and others like it generated much contemporaneous commentary while exposing the interests, aims, and intrigues of the diverse denominational, political, economic, and ethnic interests directly involved. Moreover, because it represents one extreme, to be fully understood, this Chippewa case must be compared with other cases of Old Northwest Indians subject to dislocation and resettlement. By examining the Lake Superior Chippewa case both intensively and comparatively, we can better appreciate how Old Northwest Indian communities reacted resourcefully and variously to American policy initiatives. In the Chippewa case the Indians drew effectively on a variety of relationships with and the support of Wisconsin citizens to oppose the interlocking national, regional, and local patronage system which, rather than "settlement pressure," had fueled the drive for their relocation.

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Although these Chippewa were certainly victimized by a few American officials and punished by events under no individual's control, ultimately they emerged from this confrontation as victors. During the three years following the abortive effort to dislodge them, they effectively maneuvered, procrastinated, and negotiated to a standstill those functionaries still bent on their dislocation, and in the end achieved their major goal of remaining on reservations within their preferred habitats in Wisconsin and Michigan by explicit treaty-specified right. Moreover, the Chippewa were not alone among the Indians of the Old Northwest in successfully thwarting American efforts to implement the removal policy. Systematic study of the diverse responses of the two dozen groups of Indians in the region subject to the various tactics of Americans to move them west makes this eminently clear and contributes further insights into the distinctive features of the Chippewa case.

Of the more than forty efforts between 1825 and 1855 to bring about the westward resettlement of Old Northwest Indians, there were just four where outright force, or—as in the Chippewa example—furtive deception and trickery, were employed to produce the results desired by federal administrators. In these few cases, the coercive tactics used contributed to extraordinary hardship and fatalities, consequences that can be, in some part, plausibly attributed to the actions of American authorities. The other three involved Black Hawk's band of recalcitrant Sauk, Fox, and Kickapoo in 1831–1832, certain villages of the Indiana Potawatomi in 1838, and the Winnebago intermittently over the course of a decade and more after 1838.[5]

Although each of these four cases had its own distinguishing features, they shared a series of specific common antecedents, one or more of which were lacking in all other attempts to dislodge and to relocate groups of Old Northwest Indians. These features in combination conditioned the resort by Americans to coercion or deception. In sequence, the first of these was a serious, prolonged, public dispute over the legitimacy of a treaty obligation, with the Indians vehemently denying the right of Americans to demand the surrender of particular tracts and their resettlement and with their adversaries hewing to the right to evict. Next, such a dispute had to be moved to a crisis point, with the Indians adamantly rejecting further American efforts at verbal persuasion and the various incentives proffered. Finally, there had to be present politically influential local Americans with strong vested interests in securing the dislocation, transportation, and resettlement in particular places of the Indians involved. These interests were varied and intertwined. They included some combination of local political prestige, career enhancement, visionary dreams of ecclesiastical colonies, control of patronage resources, profound power needs, ideological convictions, the need for immediate income, the aim of thwarting rivals, the lure of capital accumulation, and others more or less distinguishable in the historical record.[6]

Lacking one or more of these three conditions, American authorities did not use force to drive Indians west in a manner that fits the "Trail of Tears" stereotype. Ordinarily, officials relied on personal influence, on oral argument (enumerating what they defined as the positive inducements for moving and the disincentives for remaining), and on the dispositions of the Indians to cooperate in what must be defined as encouraged, but not forced, migrations. Similarly, numerous groups of Old Northwest Indians, sometimes differing with Americans on the stipulations in treaty engagements, sometimes not, did not press the issue, but instead escaped or evaded the removal policy entirely. By avoiding direct confrontation, such dissidents avoided a situation in which Americans were moved to use the exorbitantly expensive, often ineffective, and morally demeaning option of armed escort and manifest compulsion.

Three different cases together represent the antithesis of the Lake Superior Chippewas' extraordinary experience. In September, 1837, the Mdewakonton Dakota (Sioux), for example, sold their remaining claim to lands in western Wisconsin in what has been called a "removal" treaty. However, their relocation was to them a profitable non-event. As their capable agent, Lawrence Taliaferro, remarked in 1836, they were only maintaining the semblance of a presence in their former territory east of the Mississippi "so as to get a good price for it in case of a desire on the part of the U States to purchase."[7] They had earlier abandoned these lands, owing to pressures from intrusive Chippewa and other ecological and social imperatives (well described by Gary C. Anderson).[8] With the help of Agent Taliaferro, who blew fluff into the ears of Washington officials about the desirability of "removing" these Indians to the west, the Dakota leaders then negotiated a treaty that provided them nearly a million dollars for lands they could neither safely occupy nor productively use. As of the fall of 1837, there were no Dakota east of the Mississippi to be "removed." Prompted and advised by Taliaferro, they had seen in the removal policy an opportunity for large profits at no cost to themselves. The Dakota were not alone among Indians of the region who recognized positive incentives in American initiatives that others, such as the Chippewa bands nearby, defined as menacing rather than beneficial.

Among those Indians who found opportunities in the removal policy were two groups that could not be touched by American authority, for they were British subjects residing in Canada. These voluntary participants came from among the Hurons of Anderdon Township and the Christian Indians (i.e., Moravian Delaware) of New Fairfield, Canada West. Both represented schismatic divisions of fully Christianized, literate, self-governing, predominantly English-speaking communities organized as townships in the Province of Canada.[9] In both these cases, the decision to emigrate came after a long irresolvable factional dispute involving efforts of the Crown to purchase large portions of their reserved estates. Those who elected to emigrate were groups who favored both the sale and emigration to the West, moves long blocked by their rivals.

In neither instance was there a hint of American influence during the preliminaries. Instead, responding to solicitations from related peoples with similar concerns in the United States, both the Moravian and the Huron factions approached American authorities for permission to participate in the removal program. For the Moravians, the invitation had come from the "Missouri Party" of the Stockbridge-Munsee in eastern Wisconsin, a faction which also favored resettlement.[10] Theirs was a considerable feat-of-arms, certainly demonstrating great enthusiasm for the journey. For in 1837 some 202 Moravians departed the Thames River valley in open Mackinaw boats, rowing their way across the western Great Lakes, via the Green Bay-Fox-Wisconsin River waterway to the Mississippi, and then traveling by steamer to St. Louis and eastern Kansas. In 1843, fewer Anderdon Hurons traveled west—making an easier trip of it by canal boat and river steamer—with their relatives and Methodist confreres among the Ohio Wyandot. In neither instance did all from these Canadian emigrant parties long remain in the Indian Territory.[11] Many soon leased or sold their "head rights" to the land they had acquired and promptly returned to Canada.

In contrast were the responses of several major groups of Indians that evaded or avoided the plans of Americans by one device or another. Numerous Potawatomi, Ohio Ottawa, and smaller numbers from other tribes slipped across the international border, using Canada as a temporary or permanent refuge, while others moved into northeastern Michigan or northern Wisconsin. Then there were more who—like those master escape artists, the Winnebago—simply refused to stay put after being repeatedly transported west of the Mississippi.[12]

Moving Indians into western lands selected by Americans for their supposedly exclusive and permanent occupation was one matter; keeping them there was an entirely different and often far more difficult one. As the exasperated Governor Alexander Ramsey complained from Minnesota Territory in the fall of 1851, "No argus-eyed vigilance on the part of officers of the Indian department can erect a Chinese wall between this tribe [the equestrian Winnebago] and the inhabitants of Wisconsin."[13] His annoyance stemmed not only from the reluctance of dislocated Indians to stay where they were replanted, but also from the willingness of many Americans near their former homes to tolerate or even ease their return. Obviously, the removal policy at this date was out of tune with the disposition of peregrinating Indians and with the sentiments of numerous citizens of Wisconsin and Michigan as well.

Although his grievance was expressed a year after the scheme for displacing the Lake Superior Chippewa was conceived and set in motion, Ramsey had been one of the four actors most responsible for the design and through 1851 had actively promoted efforts to carry it out. If other Indians like the Winnebago could not—short of building and manning a "Chinese wall"—be separated from their old homes, then what sense was there in Ramsey's conniving to transport west yet another large population of manifestly unwilling, notably ambulatory Indians?

That the Chippewa were to be settled within the governor's jurisdiction, however temporarily, is but part of a necessarily complex answer to this query. There were, to be sure, considerable political and economic rewards to be gained simply from the business of transporting Indians westward, as Ramsey knew, even should they immediately countermarch. Yet this fragment of an explanation still leaves a larger puzzle. How, in 1850, did a Secretary of the Interior, a Commissioner of Indians Affairs, a Territorial Governor, and a lowly Indian Sub-Agent come to concoct a scheme that, in the end, caused the loss of many Chippewa lives and yet left the Chippewa in Wisconsin?

The scheme was designed a dozen years after Andrew Jackson and other leading advocates of removal had declared implementation of the policy a success, "as having been practically settled."[14] The United States of 1850 was no longer the geographically compact republic anticipated in 1803 when Jefferson first conceived of defusing federal-state tensions by displacing unwanted Indians into a vast, newly acquired western territory. Nor was it the developing nation of 1825, when a "permissive" policy of community-by-community resettlement was issued by Executive Proclamation, or that of 1830, when the formal, comprehensive, nationwide provisions of the Indian Removal Act obtained congressional sanction.[15] By 1850, the ideology of Manifest Destiny had been announced and affirmed, the Mexican war won, Continentalism achieved. No national leader could any longer confidently believe that conflicts involving culturally alien, not read-

Alexander Ramsey. Governor and Superintendent of Indian Affairs for Minnesota Territory, Alexander Ramsey was a prime mover in the effort to dislodge the Wisconsin Chippewa bands and to move them and their treaty granted resources into his jurisdiction. Courtesy of the Minnesota Historical Society.

ily assimilable Indians might be avoided by relocating them "permanently" in a huge western Indian Territory on lands that would be forever theirs. By 1850, this was no more a realistic plan than was the abortive parallel policy of reducing sectional tensions over slavery by repatriating Afro-Americans to Liberia.[16]

The political pressure for Indian Removal was effectively removed by events of the latter 1840s, which saw the emergence of a geographically larger, socially more complex United States. The new continental nation was far more diverse ethnically than it had been when the removal and repatriation schemes were conceived. Nevertheless, through the 1830s and 1840s the promise of permanency of tenure on tribal lands in an exclusively Indian Territory legislated in the 1830 Removal Act (essentially a segregated native homeland or apartheid policy) was confirmed in every proper removal treaty. No such stipulation was included in those negotiated with the Lake Superior Chippewa in 1837 and 1842 for the cession of their lands east of the Mississippi. The 1850 effort to dislodge them from Wisconsin and to resettle them near Sandy Lake—east of the Mississippi—involved a temporary location only, because of their specific history of dealings with the United States.

Occupying the farthest northwestern reaches of the Old Northwest, the Lake Superior Chippewa were the last Indians of that Territory to have their independence erased by formal treaty agreement with the United States. Although placed under nominal American sovereignty in the 1783 Treaty of Paris and again in the Treaty of Greenville in 1795, this was a status unknown to these Indians—who remained in a position of unqualified political autonomy. The degree of their continuing independence was marked by two developments. Unlike other foraging bands near them, they had sat out the War of 1812, declining British invitations to join in active military operations. Thus, not considered enemies by American authorities, they did not participate in any of the several subsequent peace treaties pressed on neighboring Indians—including related Chippewa bands—when hostilities ended. These postwar compacts restored the status quo antebellum and required a fresh acknowledgement of American authority in the region, which the Lake Superior Chippewa had yet to deliver. Moreover, throughout the removal era, the Lake Superior Chippewa continued a century-old pattern of warfare against their Dakota neighbors, as good a measure as any of their autarchy and a major concern of Americans attempting to impose peace on this frontier.

Such concerns were expressed between 1825 and 1827, when three treaties were required at last to bring all these small, scattered Chippewa bands under some measure of American authority.[17] These agreements established the meets and bounds of Lake Superior Chippewa lands, declared a "peace" between the Chippewa and their Indian neighbors, defined a new subordinate political status for them, and included provisions for modest educational services and the payment of a minor annual annuity. So far as American authorities were concerned, these Chippewa thereby became dependent client societies.

Yet for a decade these agreements had little consequence for the daily lives of these Indians. No lands were ceded, while the small annuity fund and scanty Indian Office services provided were delivered mainly to those Chippewa living near Sault Ste Marie. For another full decade, contacts between the Lake Superior Chippewa and Americans, other than traders and a few ineffective missionaries, remained occasional and minor. However, these three treaties expressed the legal foundation for the Chippewa's political and economic future. The "tribal" boundary agreements, for example, were intended to ease, and were later used for, land sale negotiations, whereas at Fond du Lac (Duluth) in 1826, American negotiators had obtained a vaguely defined privilege from the Chippewa: "to search for, and carry away, any metals or minerals from any part of their country."[18] Sixteen years later, when at La Pointe the Chippewa were pressed hard to cede their last remaining lands east of the Mississippi River, this seemingly minor stipulation about exploration for mineral samples was used as a weapon to defeat their resistance.

For nearly a decade following acknowledgement of their dependent status, few new settlers or entrepreneurs appeared among them, especially in the interior away from the watercourses. Then, in 1836, a variety of developments prompted both Chippewa leaders and American authorities to arrange the first of a series of land cession treaties. Among the Chippewa, the initiative came, significantly, from those along the upper Mississippi River, who with other bands were increasingly disturbed by declining income from the fur trade and were jealous of neighboring native peoples receiving annuities from the United States when they had none. Taking advantage of Joseph N. Nicollet's exploration of the Mississippi's headwaters, these Chippewa sent a delegation with this French astronomer-mathematician on his return to Fort Snelling. There Flat Mouth of the Pillager band near Leech Lake, the most prominent leader among the Mississippi bands, declaimed a list of their miseries and wants. Other tribes, including the Chippewa of Michigan, he complained to Agent Lawrence Taliaferro, "are doing better than us. They have treaties we hear, and they have goods and money. . . . We hear of treaties every day with our Nation on the lakes and yet not a plug of tobacco reaches us on the Mississippi . . . we wish to know when we might have our expectations realized."[19]

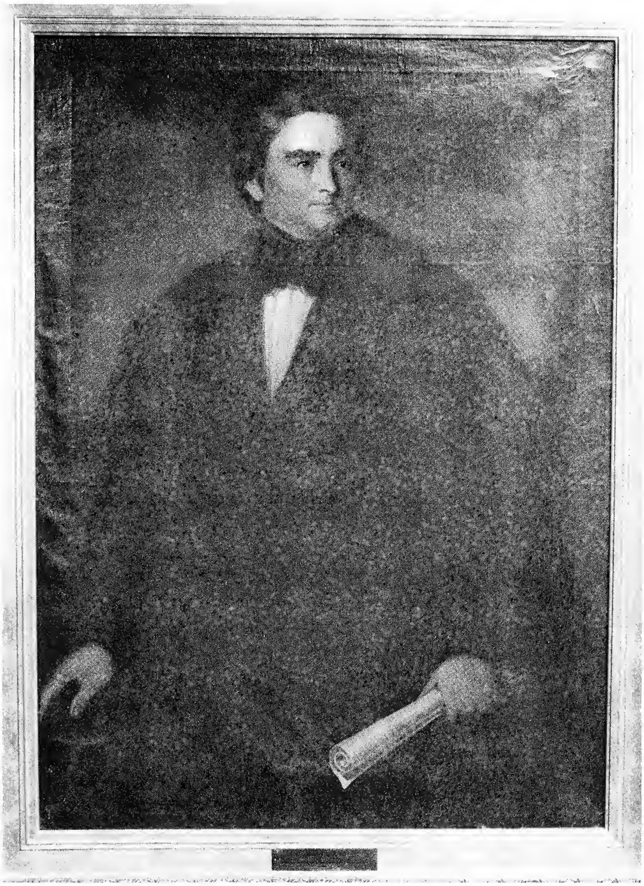
Unknown to the Chippewa, American authorities were already moving to arrange a cession of portions of their lands. That February the Senate had directed the Executive Branch to arrange a purchase of tracts north of the Wisconsin River. Seen from Washington, the aim was to obtain control of the shores of Lake Michigan and the Upper Mississippi, both to make the whole course of that stream the "barrier" between Indians and the organized states and territories and to gain legitimate access to the vast pine forests of the region.[20] The latter represented a legislative response to the growing demand for pine lumber to build the proliferating new towns of the Mississippi Valley, a demand that had far outdistanced the supply of reasonably priced lumber shipped from western New York and Pennsylvania. Moreover, on the edges of the Chippewa's pine forests proper, a coterie of long-resident entrepreneurs, recognizing a profitable new market when they heard of it, were already maneuvering to obtain private control of these valuable Chippewa resources. These were the old-line principals in the fur trade, the heirs and assigns of the dismantled American Fur Company, as well as smaller independent traders, led by such notables as Hercules L. Dousman, Samuel C. Stambaugh, H. H. Sibley, William Aitken, and Alexis Bailey.

For a number of years, these experienced local residents had been exploiting their personal ties among the Chippewa and other tribes, obtaining from them leases for sawmill sites and timber cutting rights in "Indian country."[21] Operating in the gray areas of Federal Indian law, their activities were scarcely slowed by an imperative directive from the Commissioner of Indian Affairs prohibiting such private contracts. In early 1837, the Commissioner dispatched a trusted investigator, Major Ethan Allen Hitchcock, to evaluate the situation. He reported that water-power sites and locations for dams and impoundments along the streams in the pinery region, vital for timbering, were few in number. Hence, unregulated, the American Fur Company's successors could quickly obtain exclusive control of timber resources, which would block broader development of the region. From Fort Snelling, Agent Taliaferro reinforced Hitchcock's reports, emphasizing—so he claimed—the opposition of these entrepreneurs to government interests and the growing antagonism of the Chippewa to them. Later, Wisconsin's territorial governor, Henry Dodge, expressed additional reasons for defining a serious threat in the efforts of this cabal: they were, he charged, loyal to British interests.[22] Thus, in addition to the concern with maintaining the government's ascendancy in managing Indians and the need to promote extraction of pine timber vital for regional development, two Jacksonian specters hovered over the preliminaries to the Chippewa's first land cession: the threats of private monopoly and of increased British incursions into the economy of the Northwest frontier. Underneath, however, the real threat was one of old-resident, locally influential individuals to the established Democratic patronage system, interests that threatened the flow of political benefits to the faithful.

In May, 1837, Governor Dodge received instructions for this first Lake Superior Chippewa land sale. Therein the Commissioner of Indian Affairs narrowly emphasized to him the importance of acquiring the pine lands but forbade recognition of any existing private leases for lumbering, which in the end only provoked a land-rush for key sites even before the treaty was ratified (Fig. 1).[23] Although a comprehensive national removal policy was then being implemented, no hint of such a provision was contained in these instructions or expressed during actual negotiations. On the contrary, Governor Dodge was directed to press for use of the proceeds for long-term local Chippewa social and economic development on their remaining lands in Wisconsin and Minnesota and to determine whether the western Chippewa bands would allow the United States to resettle the Ottawa and Chippewa of Michigan among them. From the perspective of Washington and the officials of Wisconsin Territory, there was yet no need to bring about the dislocation and westward "removal" of these Chippewa bands. Instead, they were expected eventually to resettle voluntarily among their kin to the north and west.[24]

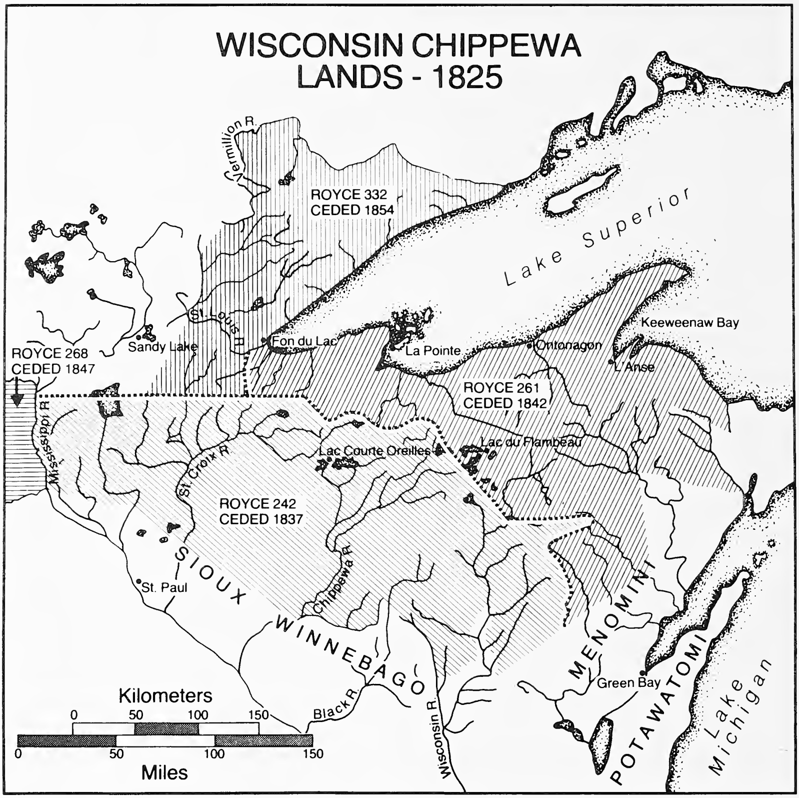
Practical arrangements for this parley created immediate and long-range problems. Since the Lake Superior Chippewa had been in an administrative never-never land (their villages were located between and remote from the Indian agencies at Sault Ste Marie and Fort Snelling), they had never been effectively served by any Indian agent.[25] The latter place was convenient to Governor Dodge's offices in Mineral Point, close to the Mississippi River traffic-way in extreme southwestern Wisconsin. But his selection of Fort Snelling as the treaty grounds placed arrangements for the meeting in the energetic hands of Agent Taliaferro. Taliaferro was rarely slack in promoting the interests of Indians within his jurisdiction—in this instance the Chippewa bands of the Upper Mississippi—nor reluctant to thwart the influence of his rival at the Mackinac Island-Sault Ste Marie Agency, Henry R. Schoolcraft. Thus from the start, the Mississippi bands, only a small fraction of whose lands were involved in this negotiation, were administratively much favored.

The second cluster of Chippewa in-



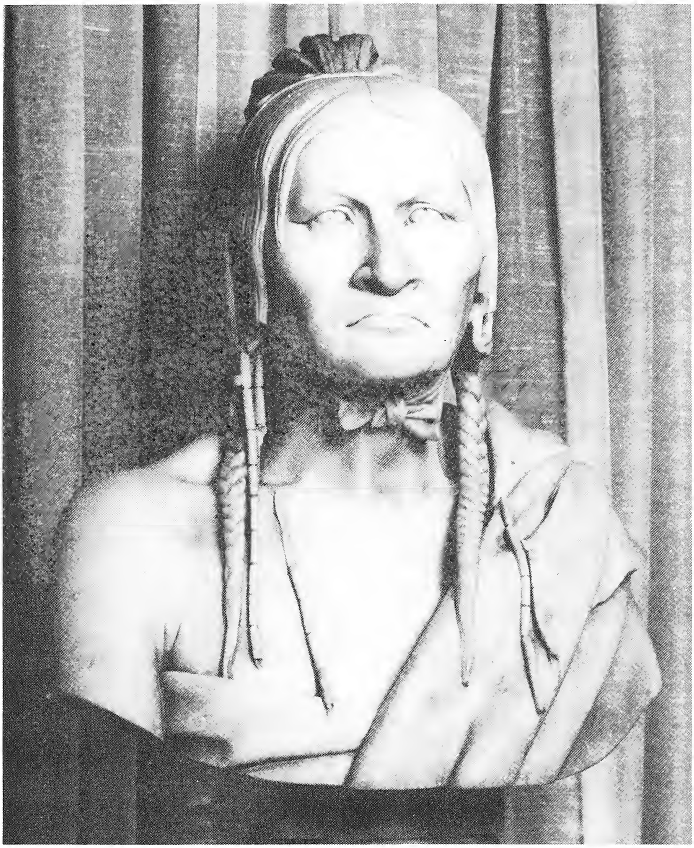
Henry Dodge. When governor of Wisconsin Territory in 1837, Henry Dodge negotiated the Treaty of 1837, and later defended the Chippewas' rights under the 1842 treaty to occupy and to exploit their ceded lands for "many years." Courtesy of the State Historical Society of Wisconsin.

volved were from bands on the Lake Superior shoreline, and none of their lands were ceded that year. Lastly came the interior Wisconsin Chippewa of the Mississippi River's eastern watershed, whose lands were on the block that summer. These interior bands did not receive an official announcement of the treaty, and few of their leaders arrived at Fort Snelling in time to participate in or benefit immediately from the arrangements. This happened because neither of the two newly appointed sub-agents dispatched to carry word of the meetings—Miles M.



Vineyard from Crow Wing above Fort Snelling and Daniel P. Bushnell from La Pointe—visited the interior Wisconsin bands. Indeed, a year later Bushnell still hardly knew the locations of the bands he served or the boundaries of his subagency.[26]

Although in earlier treaties the Chippewa had been identified as a "tribe," the treaty sought at the confluence of the Mississippi and St. Peter's rivers in July 1837, was negotiated with a new, American-conceived political-administrative fiction, the "Chippewa Nation." The use of "nation" did not denote any sense of political sovereignty. Instead it was used as a means of dealing with the several Chippewa bands collectively. This novel appellation allowed American authorities to negotiate with some of their delegates as if they represented all and to treat the whole of the lands they occupied as a "national" estate, a concept alien to traditional Chippewa thinking. But while the leaders from the bands on the Lake Superior shore demurred, on the principle that the tract being ceded were not theirs to sell, the powerful chiefs from the Mississippi bands made no attempt to disabuse American negotiators of this



Chief Buffalo (Psheke). Old Psheke of La Pointe, the senior leader and speaker of the Lake Superior shore line Chippewa bands, led the opposition to resettlement in the west and the drive for reservations in Wisconsin. The marble original of this portrait bust was carved from life by Francis Vincenti in Washington, 1855. Chief Buffalo was then about ninety-six years old, and he died later the same year. Courtesy of the Architect of the Capitol, Washington, D.C.

misconception. Indeed, since they had little to lose and much to gain, they dominated the proceedings, intimidating their kin from east of the Mississippi. The few leaders from interior Wisconsin, whose lands were being disposed of, arrived late and scarcely raised their voices.[27]

On the American side of the conference table, although instructed to obtain an outright sale of the whole region, Governor Dodge repeatedly said he wanted only control of the pine forests. Recognizing an opening when they saw it, the Chippewa instructed their official speakers, Magegabow (The Trap) and the elder Bugonageshig (the elder Hole in the Day) in their reply.[28] On July 27, Magegabow, in flowery words embellished by symbolic gestures, tried to communicate the Mississippi bands' chiefs' interim negotiating position. The Chippewa, he proclaimed, would sell the particular lands wanted by Americans, but they wished "to hold on to a tree where we get our living, & to reserve the streams where we go to drink the water that gives us life." The Secretary recording these debates, Verplanck Van Antwerp, was nonplussed, noting in the margin of the minutes, "This of course is nonsense . . . I presume it to mean that the Indians wish to reserve the privilege of hunting, fishing, etc. on the lands." Clearly, this was not the American intention. Just as clearly, the Chippewa leaders understood their adversaries' aims of acquiring clear ownership of the whole tract.

Meanwhile, Magegabow continued, laying an oak bough on the table before Governor Dodge and saying, this is "the tree we wish to reserve. . . . It is a different kind of tree from the one you wish to get from us."[29] Although these Mississippi bands' spokesmen had no direct interest in the lands being sold, they were declaring their willingness to sell pinelands (useless to them) and their desire to reserve from the sale the deciduous forests and the waterways, which were of particular value to the interior Chippewa as the game-poor coniferous forests were not. Certainly the Mississippi bands' leaders understood the American aim to purchase the use and occupancy rights to the whole region outright, for the governor had repeatedly explained this both before and after Magegabow's speech. What they were doing was hedging, inserting a qualification into the official record, one they could later use to dodge undesirable ramifications of the agreement or to reopen negotiations.[30]

The participating Chippewa finally approved an outright sale of the whole tract. Notably, no mention of removal from the lands was inserted into the agreement; neither had there been any discussion of this matter. Instead, the treaty awarded the Chippewa the temporary privilege of residing on and taking their subsistence from the habitat ceded, "during the pleasure of the President." With these words the Senate delegated to the executive branch the necessary authority to determine when, in the future, Chippewa rights to occupy and to exploit the pine lands should end. Certainly, the Chippewa, at the time, construed these expressions to mean a very long time. Since they could see few Americans in their lands and since it was to be years before their basic adaptations were much disturbed by aliens there, they had no reason to think otherwise. Indeed, American officials at the time expressed no definite ideas about when this privilege would be withdrawn.

However, an eyewitness to the negotiations recorded a foreboding judgement about the "pleasure of the President" phrasing, not about the timing, but about the way this privilege would ultimately be withdrawn. Writing to his superior in Boston, missionary W. T. Boutwell predicted "trouble with the Chipys. before five years should they attempt to remove them . . . the Inds. have no idea of leaving their country while they live—they know nothing of the duration of a man's pleasure."[31] An experienced observer of Chippewa ways, Boutwell was commenting on several social facts. The scattered, politically decentralized Chippewa, especially those in Wisconsin, would not feel themselves bound to contracts made by distant chiefs not their own, and they would likely resist a later order to abandon the ceded lands issued by any remote authority figure such as the President.

But so far as American authorities were concerned, a firm agreement had been reached: the lands wanted had been acquired by outright purchase, while continued Chippewa use of the area was impermanent. So, too, were realized certain of the "expectations" expressed by Flat Mouth the previous year. Those Chippewa at the treaty grounds received a modest amount of goods, and the bands later got the benefits of a substantial twenty-year term annuity. For a time the annual payments—whether goods or money—were shared among some of the constituent bands of the fictive "Chippewa nation," especially those from the Upper Mississippi and from interior Wisconsin. Although few of the latter had participated in the negotiations, after protesting the next year, they finally accepted the treaty's terms when assured they would share in these annual payments.[32]

The Lake Superior shoreline bands, however, by their own choice were excluded from the annual compensation. Nonetheless, a few of the latter were soon issuing complaints like those of Flat Mouth in 1836, expressing envy of those bands who were receiving payments from the United States and indicating a disposition to sell additional lands in exchange for annuities. Some American authorities, too, were concerned with this disparity, particularly because the lakeshore Chippewa still regularly visited British posts to receive "presents," stipends supposedly "5 times" greater than the annual per capita payments from the 1837 treaty.[33] Meanwhile, in the interior, the lumber rush was on. Hardly had the treaty been signed when the old resident entrepreneurs, whose maneuvers had helped precipitate the cession in the first place, flooded into the pine lands, there preempting prime mill sites and timber tracts well before the treaty's ratification, land surveys, or public sales.

The resentments of Lake Superior-shore Chippewa were exacerbated by a decision reached by American authorities. Although the large, long established traders lobbied for Fort Snelling or—ominously—Sandy Lake, as the point of distribution for annuity goods, and while the Chippewa recipients themselves preferred several locations convenient to their villages, the Office of Indian Affairs fixed on La Pointe as the one place where the Chippewa had to gather yearly to take delivery of their treaty dividends. Therefore, for several years the lakeshore bands had to stand by and watch as those from the west and south assembled amidst them to receive payments. Certainly, significant parts of the goods and money delivered initially to the visiting Chippewa delegations quickly flowed, through long-established kin ties and reciprocal exchange networks, into the hands of the Lake Superior hosts. But this could not have satisfied the chiefs of the lakeshore villages, who witnessed their counterparts, especially the notably imperious and ostentatious leaders of the Mississippi bands, receive recognition and rewards denied to them. Thus more fuel was added to a growing discord, which soon pitted all Wisconsin Chippewa against those from the Upper Mississippi.[34]

However, at the time, no one recognized the truly hazardous economic transformation then emerging. For many decades, these Chippewa, as specialized winter trappers, had been involved in flexible, personalized, predictable exchange relationships with individual traders. Now they were collectively dependent on a complex, ill-organized, impersonal federal appropriation-purchase-transportation-accounting-delivery system, a cumbersome arrangement that rarely brought payments due to a place on a date compatible with their own seasonal subsistence work. Over the next decade the Chippewa learned that this system seldom worked satisfactorily: long delays and interference in late fall wild-rice gathering and winter hunting, not to mention the costs of long distance travel to the payment grounds, were the rule. On the other hand, there were unanticipated benefits from the treaty. As the clear-cutting of pine forests progressed, the size of the ecotone—the pine forest-prairie "edge" where white-tailed deer flourished—was vastly increased. Since deer were the most desirable and the prime source of food for the interior Chippewa, as the size of the herds increased the subsistence value to them of the lands they had ceded was also enhanced. This ramification was precisely contrary to standing American preconceptions: that the advance of "civilization" would cause a decline of available game and the voluntary migration of the "primitive Indian hunter."[35]

Nonetheless, although the issue had not been raised during the 1837 negotiations or by the Senate in ratifying this accord, Indian removal was in the air, for the resettlement of Indians from other parts of the Old Northwest was then being pressed vigorously. In response to rumors of such dislocations and reactions from the Chippewa, local Indian agents regularly advised their supervisors that the Lake Superior Chippewa would resist this threat with all means available to them. There was, simultaneously, little or no indication from neighboring citizens that moving the Chippewa was a desirable tactic.[36]

But these Chippewa had to cope with the real danger of treaty stipulated resettlement in the west during September, 1842. That month the same three clusters of bands that had negotiated the 1837 agreement gathered at La Pointe to debate a second cession, this one involving all remaining Chippewa territory in Wisconsin and Michigan's Upper Peninsula. Again the Americans sought, not agricultural lands, but control of a valuable natural resource, the copper-ore rich tracts along the Lake Superior shoreline.[37] The treaty dealings at La Pointe were in striking contrast to the 1837 council. At the earlier sessions, negotiations were, by the standards of the day, conducted in an open and aboveboard fashion, despite some manifest miscommunication and confusion. In 1842, the meetings provoked angry discord between opposed parties and a lasting controversy.

Before the final 1842 treaty document was signed, the chief American negotiator, Robert Stuart, had to engage in a variety of tricky tactical moves and coercive threats to force through an agreement. Moreover, to secure the consent of the parties most imperiled—Wisconsin's interior and the Wisconsin-Michigan Lake Superior shoreline bands—he had to issue firm verbal commitments, explicit stipulations not written into the formal agreement. Stuart (long a senior agent of the American Fur Company, recently appointed to succeed Henry R. Schoolcraft as head of the Mackinac Superintendency) faced an unusually complex and contentious situation. In addition to his duty to the United States, he had firmly in mind the fiscal needs of his former employer, John Jacob Astor. Moreover, he confronted an unruly assembly of diverse and generally opposed interests: old trading firms and newly established ones, several denominations of missionaries, mining entrepreneurs, the culturally marginal "half-breed" community, commercial fishermen, and—by no means the least divided or quarrelsome—the Chippewa themselves.[38]

The latter were now separating decisively into two divisions, those from the Upper Mississippi, and those who occupied the lands ceded in 1837 and the tracts to be sold at this meeting. Moreover, because control of the last of the Chippewa's Wisconsin lands was at issue, all involved were possessed of more than the usual windfall mania, which often stimulated dramatic confrontations at Indian treaty proceedings during this era.[39]

Thus in October the parties gathered in a variously expectant, threatened, or angry mood. Most of them, "who otherwise before-time was but poor and needy, by these windfalles and unexpected cheats" eagerly anticipated obtaining some benefit, security if not wealth.[40] They milled about for days and nights eager to shake free of the great treaty tree—each in his own direction—some of its perennial fruits.

The instructions Stuart received from Commissioner Thomas H. Crawford were of a sort to vex or inflame most of these interest groups. He could allow no payment of traders' claims on the treaty grounds, a provision subsequently softened. Neither personal reservations for half-breeds or "friends" of the Indians, nor band reservations for the Lake Superior Chippewa were allowed. Most important for the future of these Indians was the unyielding two-stage requirement for their dislocation and resettlement. Those Chippewa immediately affected offered no opposition to the first of these, the plan for their immediate abandonment of those particular tracts containing copper ore. Neither did they oppose the cession of nearly all their remaining lands. They demanded, however, several small band or community reservations, both within the area ceded in 1837 and the lakeshore region now on the table for disposition.

Stuart's instructions about the removal provision, however, were firm. The Chippewa would have now to agree one day to abandon the land sold and to resettle in the remaining "national" lands west of Lake Superior, that is, in the territory of the rivals, the Mississippi bands. But the Commissioner of Indian Affairs had stressed, and Stuart in council repeatedly emphasized, that this second step migration would not be required for a "considerable time," not until "policy" required the President to call for their relocation.[41]

On that issue—the timing of their resettlement—the fate of the negotiations hung. While Stuart readily disposed of the traders' demands and those of the half-breeds, the removal issue so threatened the Wisconsin bands that they resisted obstinately. It was then that Stuart resorted to a heavy-handed deception, claiming that the Chippewa had already ceded the mineral tracts in 1826, an allegation that the Chippewa delegates (and their American allies) denied. Ultimately, to obtain substantial support for the treaty from those nominally in control of the lands, he introduced a decision-making novelty—majority rule. The lakeshore and interior bands, relying on the traditional requirement of a consensus, were thereby outmaneuvered. Unaffected by the cession or the removal provisions, and in line to reap yet more benefits at no cost to themselves, the eager chiefs of the Mississippi bands quickly gave Stuart their "votes." They had no more intention of welcoming the Wisconsin Chippewa into their lands than the latter had of moving there. For entirely different reasons, so, too, did the small Catholic and Methodist mission communities on the Keweenaw Peninsula cast their "votes" for Stuart's proposals. This minority of christianized Chippewa believed that they could avoid removal by becoming landowning, tax-paying, farming citizens of the State of Michigan.[42]

Even so the Wisconsin bands balked and protested. Stuart then inserted into the oral record a critical clarification and stipulation. Yes, he and the Chippewa soon agreed, they would immediately have to give up occupancy and use of the copper ore tracts proper. Additionally, some day in the future the President would likely require the Chippewa to abandon all the lands being ceded and to settle elsewhere. The question pressed by the Chippewa chiefs was—when? In the distant future, replied Stuart. Be more

Robert and Elizabeth Stuart. When the Wisconsin Chippewa were pressured to leave Wisconsin in the mid-1840s, Superintendent Robert Stuart defended their right to remain for fifty to one hundred years, an explicit commitment he had made while negotiating the 1842 treaty. Courtesy of the State Archives of Michigan.

specific, demanded the suspicious chiefs. Not during your lifetimes, nor those of your children, not for fifty to one hundred years, were Stuart's phrasings as recorded by different observers. Indeed, Stuart himself later repeatedly defended the rights of these Chippewa under such mutual understandings when others violated the explicit assurances this tough-minded Scot had publicly given.[43]

Nonetheless, although most of the Wisconsin chiefs then capitulated, several remained unbelievers and refused to place their marks on the treaty document. In this manner was created the basis for a later, prolonged, unresolved dispute over the meaning of the 1842 agreement, a controversy over the issue of timing of Chippewa removal, the first necessary ingredient for the trouble that erupted eight years later. This controversy raged over what the Chippewa and their supporters (including Stuart) saw as premature demands for these Indians to move. No further condition, such as the Chippewa's "continued good behavior," had been discussed during the debates over terms, nor was any such condition mentioned in the years immediately following.[44]

However, for more than a year before the 1842 treaty, a few key actors in Wisconsin Territory had regularly misinformed authorities in Washington to the effect that the Chippewa were eager both to cede their lands and to resettle west of Lake Superior. Together with his allies, Governor James D. Doty—who had strong personal and political interests in developing the new Northern Indian Territory in Minnesota and the Dakotas—was first among these promoters.[45] Superintendent Stuart, following his first visits to his new charges, particularly after his exertions in extracting a land cession agreement from them, knew better. When the few advocating Chippewa removal continued their efforts, Stuart stood in opposition, arguing he had personally and officially promised them no removal for many years. Of greater practical importance, he pointed out, there were no obvious incentives for the Chippewa to make this move, for they had ample supplies of fish, game, and wild rice in their present locations and were experiencing few problems with the influx of Americans in the region.[46] In addition, the Wisconsin bands were by no means eager to settle among those on the Mississippi, who twice had been deployed against them to their disadvantage, especially because they knew that the remaining part of the "national" estate was an impoverished area.

Chippewa resistance to removal was reinforced because, as they understood the 1842 treaty, they could not be obligated to give up use and occupancy of the ceded lands for many years, and this construction was championed by numerous Americans directly familiar with its negotiation. Similarly, the tactics used against them in the 1837 and 1842 negotiations had led to increased solidarity between Wisconsin's interior and lakeshore bands. Facing a common threat in their politically altered environment, they began responding with better coordinated opposition. Prompt organization of their dissent was imperative, for within a year following the treaty, new pressures developed for their immediate dislocation. Despite the early opposition of Superintendent Stuart, Commissioner of Indian Affairs Crawford, Governor Dodge, and others, who variously argued that immediate removal was against the spirit of the treaty expressed in explicit verbal stipulations or that it would not benefit the Chippewa, this pestering continued and increased in strength. Wisconsin Chippewa opposition came into clear and successful focus in 1847, when the United States made an abortive effort to secure the cession of the mineral-rich north shore of Lake Superior.[47] Knowing how much Americans valued control of that region, the Wisconsin Chippewa used as a bargaining token their rights to this—for their economic purposes—barren landscape. Without a treaty-guaranteed right to remain in Wisconsin, the Chippewa would have nothing to do with negotiations for the cession of the north shore, which they managed to block until 1854, when their demands for reservations were finally met.[48]

When efforts to talk the Chippewa into

migration continued following the unsuccessful 1847 treaty councils, these communities stepped up their political opposition. Meanwhile, they proceeded along self-defined paths toward economic improvement in place, irrespective of what views American authorities held for their future. Then, in early August, 1847, Commissioner Medill signaled the preliminary design for their removal. The La Pointe sub-agency was to be closed, its functions shifted west of the Mississippi to Crow Wing even if efforts to secure the north shore of Lake Superior were unsuccessful. In the latter instance, relocation of the La Pointe sub-agency and its services, so believed the Commissioner, would have the effect of luring some Wisconsin Chippewa west, easing the way for the removal of the remainder. Later Medill explained the government's plans for resettling all Wisconsin Chippewa that coming spring to R. Jones, Adjutant General of the Army. The Chippewa were not alone in Medills design: the Menomini, Stockbridge, and those Winnebago still in Wisconsin (then near statehood) were also targeted, together with the Winnebago in the old "Neutral Ground" in the northeastern part of the new state of Iowa. Together, these several relocations were designed to clear Wisconsin, Iowa, and southern Minnesota of their remaining Indians, leaving a broad corridor open for American movement westward, between the existing Indian Territory southwest of the Missouri River and a viable new Northern Indian Territory in north-central Minnesota.

While these distant plans were being laid, the Lake Superior Chippewa followed their own variegated agenda of economic adaptation. The 1842 treaty had added a second valuable term annuity to their annual income. Over the course of twenty-five years, they would share with the Mississippi bands yearly an additional $12,500 in coin, an equal amount in hard goods, rations, and consumables, and over $6,000 for the services of blacksmiths, farmers, teachers, and other artisans. But this was only a small fraction of their annual needs, so these Indians proceeded to make up the balance by their own enterprise. Fur- trapping continued to be of small importance, while on the lakeshore, Chippewa men were increasingly engaged in commercial fishing, either with their own equipment or as seasonal labor for Americans. As mining developed, numerous Chippewa men transported supplies, acted as guides, cut and supplied mine timber, or delivered venison and fish. Intensive gathering went on, and gardening increased, particularly of root crops; this was largely the work of women, who traded surplus vegetable foods and otherwise served the mining crews. In the interior, where the timber industry was expanding along the lower river valleys, similar changes in economic behavior occurred, attuned to the labor and material requirements of that extractive industry.[49]

Some few Chippewa, particularly those on the Keweenaw Peninsula, as well as at the Reverend L. H. Wheeler's experimental station at Bad River, even approximated the old expectation of ill-informed American philanthropists by engaging in sometimes productive, male-managed, animal-powered small farming, although most others strongly resisted this novelty, risky at best in these latitudes. The substantial development, notably, lay in individual wage work and small-scale commercial enterprise, primarily in extractive industries, not in agriculture. But of greater long-range importance was the growing recognition among the local American population—most of whom were entrepreneurs, managers, or laborers, nearly all male, not under-capitalized small farmers with families seeking cheap land—that the Chippewa were delivering services and goods important to their enterprises. The Chippewa were creating tight social and economic bonds with potential allies in their immediate neighborhood.[50]

Thus, by early 1848 one necessary antecedent of a high stress, forced relocation was firmly in place: there was a prolonged, irresolvable dispute between Chippewa leaders and American national authorities over the right of the latter to demand and enforce abandonment of the ceded lands. Since Wisconsin's statehood was imminent and its laws would soon be extended over the area inhabited by the Chippewa, Commissioner Medill made a firm decision: they would have to leave. When rumors of government planning for this step reached the Chippewa they responded with a variety of political counter-moves. Some started asserting their "right" to reservations, claiming these had been promised during the 1842 negotiations.[51] But planning for relocation went on, with the 1849 establishment of Fort Gaines (in 1850, renamed Fort Ripley) on the upper Mississippi, and the reshuffling of agents and agencies aimed at concentrating the Chippewa on their remaining "national" lands in northern Minnesota. Chippewa opposition hardened as well, expressed in systematic lobbying in Wisconsin, Michigan, and Washington for the right to remain on small reserved parcels within the bounds of their old estate. A few on the Upper Peninsula, aided by their missionaries, started preempting and purchasing public lands, thereby acquiring the status of taxpaying citizens under state law.[52] Meanwhile, others sent delegations to plead their case in Washington.[53]

The Chippewa delegations to the nation's capital did not find an attentive reception, for throughout 1849 and 1850 Congress and President Taylor were preoccupied with larger issues such as incorporating the far West into the American state and the associated crisis regarding the extension of slavery in new territories. Nevertheless, despite the unconcern with the desires of several thousand Indians in an already established Free State, various political-administrative developments combined to create a national and a local context for what Methodist Missionary John H. Pitezel, an eyewitness on the Lake Superior scene, subsequently called a "chain of distressing evils."[54]

President Taylor's patronage sweep through the positions controlled by his office created the official team directly responsible for the Chippewa's winter disaster. Since the Indian Office had been transferred to the new Department of the Interior, relations with these Indians were brought under the supervision of a Taylor loyalist, Thomas Ewing of Ohio, a man more concerned with problems of the distant West than with those in northern Wisconsin. Secretary Ewing, however, strongly favoring the trading firms, kept a firm grip on the details of managing the Indian business, causing the new Commissioner, the Kentucky Whig Orlando Brown, much frustration. The third member of the administrative chain responsible for arranging the attempt to move the Chippewa out of Wisconsin was the Pennsylvania Whig, Alexander Ramsey, who in March, 1849, was appointed Governor and Superintendent of Indian Affairs in the newly formed Minnesota Territory. This trio had little experience in the management of relations with Indians, but the team was not yet complete. It was awaiting its fourth, junior but key, member, Sub-Agent John S. Watrous.[55]

Until this time, the relocation of the Lake Superior Chippewa had been little more than an administrative intention; no specific mechansim for accomplishing this aim had been created. Neither had there been an immediate impetus for translating thoughts into deeds. Excepting the Lake Superior shoreline and the river valleys traversing the pine lands, most of the ceded Chippewa lands were entirely unpopulated by Americans. The fact that the Americans residing nearby were almost entirely male likely reduced rather than increased local support for removal. However, there was simply too little "settlement" anywhere to create local "pressure" for removal.[56] In addition, although they adamantly held to their right to remain in Wisconsin, the Chippewa had not forced the dispute to a confrontation point. Instead, still holding title to the north shore mineral lands, they remained pacific and reasonable, employing lobbying and bargaining tactics, seeking approval for reservations within their old estate.

The thrust, but not an explicit mechanism of Chippewa removal, derived from the appointment of Governor Ramsey, who was the titular head of the Whig party in Minnesota Territory as well as Governor. Being one of the few Whigs in a frontier Democratic stronghold and expected to deliver economic favors to party loyalists, his position in this new Territory was particularly difficult. Thus, concerned with patronage and with establishing a firm presence in his new office, when counseled by a powerful Minnesota trader, H. H. Sibley, Ramsey could see that the Wisconsin Chippewa presented an opportunity. Obtaining their removal meant also transferring their large annual annuities and the numerous salaried jobs associated with their management into his superintendency. As well as moving an important patronage resource out of a Democratic state into his hands, the resettlement would also have meant a policy coup, a major step toward rejuvenating the floundering plans for a Northern Indian Territory.[57]

The April 22, 1850, appointment of John S. Watrous as the new Chippewa sub-agent added a critical figure, a man with at least some experience in the region and among these Indians, and one with a profound vested interest in seeing them dislodged. Originally from Ashtabula, Ohio, Watrous had arrived at La Pointe in 1847 hoping to make his fortune in the Indian trade, in which he was unsuccessful. Something of a political chameleon, in early April he left his desk in the Wisconsin State Assembly—where he had briefly served a Democrat constituency in the northwestern part of the state—to travel east in search of greater opportunity, likely drawn there by news of the Presidential order revoking the Chippewa's 1837 and 1842 treaty privileges. In Washington he presented himself to influential friends of his family as a staunch Ohio Whig and as a man experienced in dealing with the Chippewa.[58]

Watrous was a man with plans—for himself and for dispossessing these Indians. He was soon dispatched to his new post carrying Commissioner Brown's official, public orders to bring about the immediate movement of the sub-agency into Minnesota Territory, as well as a covert scheme for dislodging the reluctant, wary Chippewa. Thus was combined an ongoing dispute over a treaty and several influential local actors—men with vested interests in securing a removal. A potential disaster lay waiting only the major confrontation that the Chippewa had been avoiding. Guided and supported by his superiors in the administrative hierarchy, particularly by Governor Ramsey, Watrous soon manufactured this confrontation.[59]

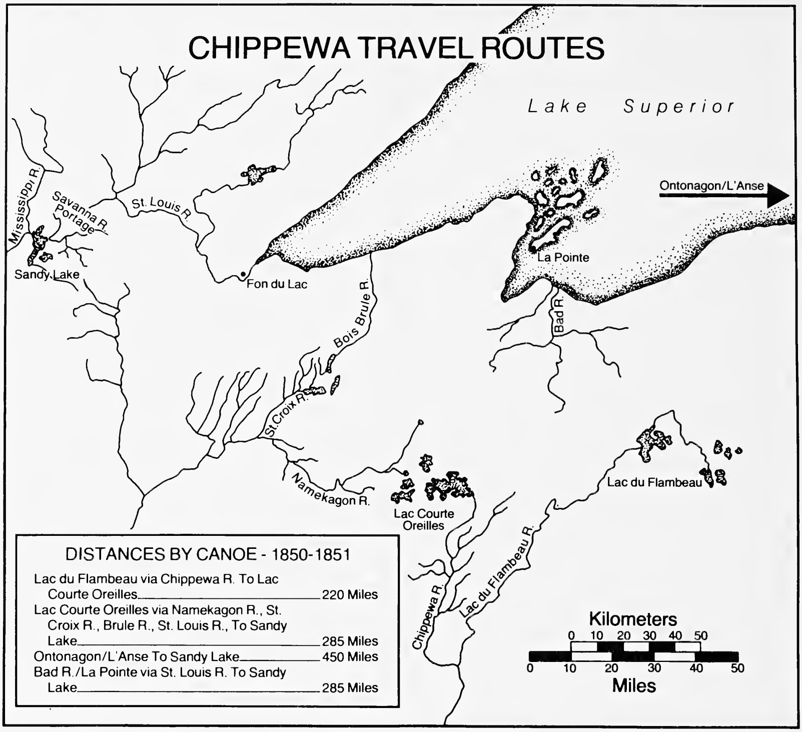
The public version of these plans specified a summer, 1850, timing for the relocation. However, aside from closing down the sub-agency's operations in Wisconsin and Michigan's Upper Peninsula, Watrous did little to bring about the move that early. Indeed, there is no suggestion anyone believed the Chippewa would cooperate had such an attempt been made.[60] Aside from Ewing, Brown, Ramsey, and Watrous, few if any others knew of the covert, contingency design, timed for a tricky, hazardous, early winter dislocation. In any respect, news of the President's executive order withdrawing the privilege of occupying the ceded lands spread rapidly, and the reaction was equally swift. While the Chippewa and their American allies began mobilizing for political resistance, there was also much demoralization. Of those who had been farming, many would not plant crops that spring; many more spent long periods in councils debating how to avoid resettlement. The time and energy spent in political agitation and the wasted economic inactivity resulted in decreased food production that summer and fall. The Chippewa became even more dependent on government rations, which contributed to the winter debacle.

Protestant and Catholic missionaries associated with the Indians were divided in their reactions. Being largely dependent on federal funds for their operations, they had to tread lightly; the position most commonly expressed was one of ambivalent neutrality, and none rose to a heroic defense of the Chippewa. On the one hand, they deferred to presidential authority; on the other, they had to consider what they saw as their responsibilities to the Chippewa, which were, mainly, to see to the future of themselves and their schools and missions among the Indians. Most commonly, while not actively supporting or opposing relocation, they would not counsel the Indians to move or stay.[61] In the end, only a few became active advocates of resettlement. The Reverend Sherman Hall at La Pointe was one. Soon after taking office, Watrous acquired Hall's loyalty with the promise of an important job at the proposed new Indian boarding school in Minnesota.[62]

However hesitantly, soon some missionaries quietly began aiding the Chippewa in framing their petitions and helping to mobilize help from other Americans in the region. One active and effective supporter was Cyrus Mendenhall, a mining entrepreneur associated with the Methodist Episcopal Mission Society, who on an inspection trip along the Lake Superior shore in June, 1850, circulated a memorial among Americans calling for the recall of the removal order. Most merchants, mine foremen, lumbermen, and other influential citizens between Sault Ste Marie and La Pointe responded to Mendenhall's appeal, which was subsequently delivered to Congress and officials in Washington. Mendenhall kept up the pressure and was soon joined by the Reverend S. B. Treat (Secretary of the American Board of Commissioners for Foreign Missions). Their lobbying effort grew in force and did not end until after removal order was withdrawn two years later.

Indeed, from the start there was no evidence of local public support for the Chippewa's removal. Regional newspapers, echoing and reinforcing the sentiments of their readers, regularly criticized the President's order and both the motives for and the tactics employed in efforts to implement it. Sault Ste Marie's *Lake Superior News and Mining Journal* was consistently strident in its support of the Chippewa, and its editorials and news clips were picked up and reprinted throughout the Great Lakes area. The Chippewa even made the news in Boston, when one of their delegations passed through on its way to Washington. The fact that the whole region occupied by the Chippewa was strongly Democratic did not aid the Taylor administration in its efforts to dispossess them.[63]

Meanwhile, Sub-Agent Watrous worked at implementing the public version of his orders. He first conducted an inspection tour of Sandy Lake (Fig. 2), the new site where the Chippewa annuities were to be



distributed. There he began arranging his own future as well, at that profitable intersection between private enterprise and public business. He established a mutually promising relationship with the agents of Chouteau and Company, the St. Louis firm that dominated trade in that area, and with potential contractors, suppliers, and transportation firms in St. Paul. By the end of July, 1850, he enjoyed a freedom of action greater than most Indian agents, for three key figures at the top of the Whig political hierarchy and national administration were gone, with the death of President Taylor and the resignations of Secretary Ewing and Commissioner Brown. Meanwhile, Congress was violently debating the Great Compromise, not mundane domestic matters such as the Indian Appropriation Bill. Thus an unanticipated ingredient was added to Watrous's covert plan—whatever he did or abstained from doing, the vital Chippewa annuity money would certainly be dangerously late in arriving. At the same time, the Chippewa were celebrating what seemed to them a success. Watrous had led them to believe that they had only to come to Sandy Lake—285 to 485 difficult canoe and portage miles to the west—to receive their annuities. Some Chippewa determined to do this, while all understood that they could for many years remain in Wisconsin even if it meant giving up the treaty specified annuities and local services of blacksmiths and farmers.[64]

These Indians and local citizens had no inkling that, earlier in the year, Commissioner Brown had sent Governor Ramsey a different set of orders and a plan, which Watrous, if not himself its principal architect, was certainly aware of before he left Washington in late April. This plan was never made public, allowing Ramsey and Watrous later to deny that a removal had ever been intended during the winter of 1850–1851. The scheme was straightforward. Annuity goods and money were to be paid only to those Chippewa who traveled to Sandy Lake accompanied by their families. These payments were not to be made in late summer or fall, because then the Chippewa would simply return to "their old haunts." Instead, the payments were to be made only after winter had set in, preventing travel by canoe. Someone, most likely Watrous, had advised the Commissioner of the Chippewa's great aversion to overland winter travel. Lured by their annuities, they were to be trapped near Sandy Lake by winter's freeze.[65]

In early October, the Lake Superior Chippewa were informed that both their cash and goods annuities would be waiting for them at Sandy Lake on the 25th of that month, a date already dangerously late in the season, which guaranteed at minimum further disruption of their own seasonal subsistence work. Watrous had by then obtained the goods specified in the 1837 and 1842 treaties and had them, together with a grossly inadequate supply of rations, delivered to Sandy Lake at extraordinarily high prices. Since the new sub-agency's farms were not yet in operation, there were no public food supplies stored at that remote location. Thus, once the Chippewa received their money annuities, they were heavily dependent for basics on purchases from the local traders, since the marshy Sandy Lake region, as well as the route going and coming, were notoriously deficient in game. This deficiency was exacerbated when the upper Mississippi flooded that season, inundating the crude structures where the supplies of both the government and the private traders were stored, spoiling the inadequate amounts of flour and salt pork available, and destroying the local wild rice crop. To compound these sources of nutritional stress, the Lake Superior shoreline Chippewa had a poor fishing season earlier that year and had already experienced grave food shortages.[66]

Constructed in this manner by several key actors with personal and political goals overriding any concern they may have had for their charges, with an assist from uncontrollable natural and institutional events, a tragedy lay in waiting for those Chippewa electing to hazard the long trip to Sandy Lake. Not all the Lake Superior Chippewa accepted the high risks they could see in this dangerous edge-of-winter journey. The bands at L'Anse, Ontonagon, Pelican Lake, and La Vieux Desert refused entirely. Those from the headwaters of the Wisconsin River sent but two men, and the villages on the Chippewa River drainage somewhat more. More came from the La Pointe area villages, but in all these instances the Chippewa took precautions. Ignoring orders to bring their families, they dispatched mainly adult males. Apparently, only from those villages closest to Sandy Lake, on Lake Superior's north shore and on the upper Mississippi, did some family groups make the journey. Moreover, intending to pack the annuity goods for their communities home by canoe and on their backs, these delegations traveled light, without the rolls of birchbark and woven mats needed to sheath temporary wigwams, many even without their firearms. These decisions further contributed to the physiological stress they experienced over the next three winter months.[67]

Those Chippewa bands who sent delegations to collect their annuities coordinated their travel plans. Coming by different routes, they assembled at Fond du Lac before pressing up the difficult portages along the St. Louis River, and then via the Savanna portage to the marsh and bogs surrounding Sandy Lake. Exactly how many made the trip is uncertain. It was likely fewer than 3,000, the figure Watrous later used in boasting of how many he had "removed" that winter. Earlier, he claimed 4,000 had assembled by November 10, but this number included some 1,500 from the Mississippi and Pillager bands, present to collect their annuities, not to be resettled. Watrous never provided his superiors with careful counts or lists of those who arrived, for once confronted with the disaster his actions had caused and the great hostility of the assembled Chippewa, he distributed the remaining putrefying rations and the other goods from the flooded warehouses to those present, disregarding his orders to deliver only to family groups.[68]

Those Lake Superior Chippewa hazarding this journey began arriving at Sandy Lake in mid-October. They discovered Watrous gone and no one present authorized to parcel out the goods waiting for them; he was on his way to St. Louis supposedly to collect the more valuable annuity money. Soon the suffering began—from illness, hunger, and exposure. The sojourners lacked shelter, and most of the scanty supply of spoiled government rations were quickly consumed, leading to an epidemic of dysentery so incapacitating and deadly that American witnesses were certain it was cholera. This was soon accompanied by an epidemic of measles, which further contributed to high rates of illness and fatalities. The Chippewa were concentrated in an unsanitary, waterlogged area, with few natural food supplies available. While they lacked shelter and medical services, were unable to collect their goods, waited day-to-day for the arrival of Watrous to bring their critically needed money payments and to open the warehouses, the Chippewa's health and energy were increasingly sapped by hunger, infectious diseases, and the winter now on them. If some of these components had been absent, they might have scattered, reducing the rate of reinfection. As it was, American witnesses reported that on many days there were eight or nine deaths, so many that the few who were well could not inter the corpses properly.[69]

Watrous saw only the last days of this calamity, for he was absent from his post until November 24, a month later than the promised payment date that had lured the Chippewa west. After sending messages for the Chippewa to assemble, on October 6 he left for St. Louis and arrived there on the 21st, four days before the scheduled payment, then at least two weeks hard travel to the north. In St. Louis he soon learned that no funds had arrived and none were expected that year, information he could easily have anticipated while yet in St. Paul, for the national political crisis had so stalled Congress that for months little attention was given ordinary domestic matters. The Appropriation Bill providing funds for the Chippewa's annuities did not pass until November 12, much too late in the year for the required physical delivery of the specie to such a remote location. Watrous on October 26 finally took passage on a steamer for his return trip, but the vessel was delayed, and he did not arrive at St. Paul until November 13. There he tarried two more days, attending to his own business, mainly pleading to obtain an upgrading of his Sub-Agency and a promotion for himself. He did not leave St. Paul until the 15th, and then the onset of winter forced him to abandon his canoe and travel on foot overland, an ill augury for the sick, starving Chippewa at Sandy Lake, who had been waiting six weeks for their goods and money.[70]

The major unanticipated institutional ingredient adding to the scale of the disaster organized by Brown, Ramsey, and Watrous was the failure of Congress to appropriate funds for the Indian Department in a timely fashion. Without hard cash to purchase necessaries for the winter, the Chippewa—who in addition to the epidemic illness, great loss of life, and their general debilitation had lost an entire season's subsistence production—were in even more desperate condition. However, on arriving at Sandy Lake on the 24th and seeing the consequences of his scheme, Watrous set to work cutting his administrative losses. The idea of trying to keep these sick, starving Chippewa near the Mississippi was swiftly dropped. He then did what little he could to relieve their "pinching wants." After much wrangling over who would be responsible for the unauthorized expenditure, he persuaded the traders to deliver a small quantity of ammunition at a highly inflated cost to the Chippewa for subsistence hunting on their way home. Similarly, he drew up arrangements for the traders to deliver to the Chippewa from their stores $8,368.40 in provisions, an advance against their yet unpaid cash annuity, at what he claimed were "the most reasonable terms possible." The terms were in fact extraordinary, three to six times those of prices at St. Paul and other nearby depots. By Governor Ramsey's own estimates, this amount was barely three days supply of food, entirely insufficient for the Chippewa's arduous return trip.[71]

Finally, on December 3, with winter fully on them, when their scanty rations and goods were at last in their hands, the encampments broke up. The Chippewa left immediately, abandoning two hundred sick and a few well adults to care for them. By then more than a foot of snow lay on the ground and the streams were frozen over, preventing the use of canoes, which the Wisconsin Chippewa jettisoned along the St. Louis River or scrapped to be used as fuel for the frigid nights. Then they set off on foot along the frozen trails eastward, heavily laden with the goods for their families. By the Chippewa's own reckoning, many more died on the trails home than had died at Sandy Lake.[72]

The total mortality for this whole sorry episode cannot be determined exactly. Watrous, himself, although sometimes claiming reports of epidemics and starvation were exaggerated, admitted that more than 150 had died at Sandy Lake proper, including twenty of those left in his charge after the Chippewa departed. About two hundred was the estimate of several missionaries present part of the time at the new Sub-Agency during these events, while William W. Warren, a month after the goods distribution, reported that nearly two hundred died at Sandy Lake alone. But the best enumerations were likely those of the Chippewa leaders themselves, for they were totaling up their own deceased kin. Two separate reports from them, one from the elder Psheke [Buffalo] and his fellow leaders at La Pointe in November, 1851, and a second from the interior Wisconsin leaders a year later, agreed that 170 died during the time spent waiting at Sandy Lake, with another 230 dying on the return trip. Most of these were adults, mainly able-bodied men, an especially hard blow to these small populations. Thus, of the population at risk, something less than three thousand, the Ewing-Brown-Ramsey-Watrous plan to lure the Lake Superior Chippewa west and trap them there successfully removed some twelve per cent, by killing them. The human loss was one thing: in addition the Chippewa also lost much capital equipment (their canoes), much critical subsistence work and other productive economic activity, and they went further into debt, when they were forced to encumber unpaid and future annuity funds for survival rations.[73]

After returning to their homes, the Chippewa were even more determined to avoid removal. Neither would they at any time of the year so much as visit Sandy Lake, which they now defined as a "graveyard." Once information of the winter's carnage became public, Watrous came under sharp, continuing attack from the Chippewa and their now numerous supporters. Missionary groups, regional newspapers, and local citizens led the opposition, and the legislatures of Wisconsin and Minnesota aided, while the Chippewa themselves began organizing a series of memorials and delegations to Governor Ramsey and to Washington. Within six months the new Commissioner of Indian Affairs, Luke Lea, and the Secretary of the Interior responded to this lobbying effort, seemingly in favor of the Chippewa.

On August 25, 1851, the Secretary issued instructions apparently rescinding the 1850 removal order. Transmitted to Watrous by telegraph, this information became immediate public knowledge, spread by the *Lake Superior News* in an account highly favorable to the Chippewa. A few weeks later, leaders from the La Pointe and other bands traveled to Sault Ste Marie for a grand "Indian Jubilee" celebrating their victory. The rejoicing was premature. Although the removal order itself was publicly withdrawn, actual efforts to accomplish this goal were not ended; for the requirement that annuities be paid only to Chippewa in the west remained in force, and Agent Watrous continued determined efforts to dislodge them on an even larger scale than earlier.[74]

Backed by Governor Ramsey, Watrous had begun active, large-scale removal operations early in the year, and these continued through 1851 and 1852 irrespective of publicized instructions from Washington. Recognizing that the Chippewa would have nothing to do with Sandy Lake, Watrous selected Crow Wing and Fond du Lac as destinations more likely acceptable to them. He marshalled his forces, employed more personnel, placed influential marginals such as William W. Warren and missionaries such as W. L. Boutwell on his payroll, stockpiled resources, let contracts, issued assembly orders, called for troops to aid his work (which were refused), and scurried around the region working to lure the Chippewa out of their ceded territory, all the while affecting to keep his plans secret from the Chippewa and their American allies.

The one major incentive Watrous had was the annuity fund, now doubled because of the accumulation of 1850 and 1851 installments. To increase the pressure he refused payment in Wisconsin to any subdivision of the Chippewa: Pagan, Christian, Successful Farmer, New Land Owner, Half-Breed, Lake Shore Fisherman, Interior Hunter, whatever. And in autumn, 1851, he made plain that he still favored the same deception plan and tactics that had proved so disastrous a year earlier. "It is my intention," he reported to Ramsey on September 22, "to delay (unless otherwise instructed) making the moneyed payment of the present year to the Chippewas of Lake Superior until after navigation ceases, which is done to throw every obstacle in the way of their returning to their old homes." The governor did not otherwise instruct.[75]

However, in spite of all the preparations and expenditures, most Chippewa would have nothing to do with these plans. Many traveled to Fond du Lac or Crow Wing that fall; after obtaining their annuities, few tarried to experience a repeat of the previous year's debacle. Nonetheless, the newly promoted Agent Watrous proclaimed near total success, reporting that only seven hundred Chippewa remained in the east subject to later removal. His reports were seconded by

Governor Ramsey, who also professed victory in his Annual Report. Both were dissembling, as local citizens, employees of the removal effort, missionaries, the newspapers, and the Indians themselves well knew. The Wisconsin and Upper Peninsula Chippewa remained within their old band territories, irrespective of the change in their status caused by Wisconsin's statehood and the cession of their lands.[76]

These attempts to dislodge the Lake Superior Chippewa continued through 1852, but with diminishing effect. As the protests of the Chippewa and their allies grew in volume, and evidence of costly failures mounted, a final delegation to Washington at last produced success. Following a meeting of old Psheke from La Pointe with the President in late June, 1852, when another petition from the citizens of the Lake Superior shore was presented, Millard Fillmore finally cancelled the removal authorization entirely. Of even greater value to the Chippewa, the President now approved the payment of back, current, and future annuities at La Pointe. The Chippewa victory was complete two years later. Then, after a Democratic President had taken power in Washington, a new Commissioner of Indian Affairs, George W. Manypenny, dismantled the old Indian removal policy and installed a new program emphasizing concentration on reservations and economic development in place. On September 30, 1854, the Lake Superior Chippewa signed their last treaty with the United States, one severing relationships with the Mississippi bands, and guaranteeing them the right to reside on and take their subsistence from reservations within the environments they had long inhabited.[77]

Forty years ago, in the first attempt to find order in the implementation of the removal policy among the Indians of the Old Northwest, Grant Foreman concluded that their resettlement was, "haphazard, not coordinated, and wholly unsystematized," and further asserted that the whole period for these peoples was characterized by no pattern.[78] But if we plot the different responses of all Old Northwest Indian societies to the removal policy against the basic forms of their adaptations to broad biotic zones, their different types of social organization, and the paths and various goals of American intrusions into their lands, a clear matrix emerges. This underlying pattern yields a near mutually exclusive distribution of those Indian communities that did resettle in the western Indian Territory against those that did not. By placing their activities into a broader social context, this pattern also helps to make understandable the Chippewa's resistance to relocation.

The Chippewa of Michigan's Upper Peninsula and Wisconsin were by no means alone in their successful resistance to this American inspired and commanded resettlement program. Despite repeated efforts running over many years, the federal authorities entirely failed in efforts to dislodge any of the native societies in the Great Lakes region similar to these Chippewa in basic social organization, technology, subsistence economy, environmental adaptation, and culture.

Those Old Northwest Indians whose assessments of the removal policy were most strongly negative were foraging peoples, dependent on hunting, fishing, and gathering for their subsistence, while they exchanged for manufactured goods and money the same products needed for their own sustenance. They inhabited biotic zones characterized by numerous streams, marshes, and lakes, with long, harsh winters and extensive deciduous and coniferous forests. They were also skilled builders and users of framed-up bark canoes, their main means of transportation. And their direct contacts and experience with the western prairie lands were few or none.[79]

Thus, the Lake Superior Chippewa's success in thwarting implementation of the removal policy was true also of extensive populations of other Chippewa communities, and the Menomini, Ottawa, and those Potawatomi villages on the Lake Michigan shore above present Milwaukee. Organized as small, autonomous bands, these native peoples had maintained their political, social, cultural, and religious integrity to a degree well beyond those of Ohio, Indiana, and Illinois. Moreover, throughout the era these Old Northwest Indians were not surrounded by Americans, agriculturalists or otherwise. Hence they and Americans were not immediately in open competition for the resources of the same environments. These foraging bands, confidently following their own cultural and adaptational trajectories, recognized no advantage in westward migration away from habitats familiar to them. Instead, they defined this possibility as greatly damaging to their welfare. Indeed, several thousand Indians from these communities, when faced with the prospect of closer dealings with Americans and their authorities, did voluntarily abandon their lands in the United States. But these slipped across the international border into Canada and resettled in locations similar in climate, flora, and fauna to those they had abandoned.[80]

To the south an entirely different pattern of Indian responses to the removal policy emerged. In striking contrast to the reactions of the foraging bands in the northern reaches of the Old Northwest, when the era closed all the Indians there—with some few exceptions—had been dislocated and resettled in the west. These were multi-community tribal societies such as the Shawnee, Delaware, Wyandot, Kickapoo, and Sauk. They occupied habitats characterized by relatively long growing seasons, prairie and parklands, fertile bottom lands, and hardwood forests. They lived in large, semi-permanent villages, and their traditional economies had been based on a mix of intensive horticulture and large-game hunting.[81]

Moreover, well before the removal era began in 1825 they had been forced to adapt to a new environmental reality: large numbers of American farmers, merchants, entrepreneurs, and developers were a significant and threatening part of their milieu. Occupying the ground directly in the path of the post-Revolutionary frontier, for decades their relations with these newcomers had been marked by intense, open rivalries, for they were involved in sometimes violent competition for the same environmental resources. Thus they had long been involved in land cessions. Some, like the Mdewakanton in 1837, had more or less eagerly exchanged less critical portions of their estates for goods, immediate cash payments, and annuities. Others had been driven to such sales by intense pressures from appointed negotiators and other interested parties. Understandably, the effects of the removal policy fell on them earlier and heavier than on the northern foragers like the Chippewa. Indeed, the first treaties with any Indians— either of the Old Northwest or the Southeast—to be impelled by and obtained under the specific terms of the 1830 Removal Act were negotiated with several such communities in Ohio.[82]

These farming, large-game hunting tribal societies of the Old Northwest's prairie lands were also distinct from the foraging bands to the north in another salient characteristic. While the foragers remained committed to bark canoe transport, those to the south had long since abandoned such frail vessels in favor of horses. Indeed, twenty years before Thomas Jefferson conceived of using the newly acquired Louisiana Territory as a suitably distand homeland for Indians, numerous Shawnee, and Delaware, followed by lesser numbers of Kickapoo, Illini, and Potawatomi, had used their new means of travel voluntarily to abandon their land in the Old Northwest and resettle in Missouri and Arkansas, with some going as far west as Texas.[83] Since horses facilitated East-West movement of people and goods across the valleys of the great midcontinent river systems, even those who stayed in the remains of their old tribal estates were enabled to add seasonal horse-nomadism for purposes of hunting, trade, diplomacy, and war to their technological inventory. Oriented to large game hunting from the start, when they faced increased competition with Americans near their lands, they used horses to bring the resources of the western environments within their reach.

Hence, by 1825 not only were many from these prairie tribes familiar with the western environments, but several related pioneer Indian communities were already well established there. Indeed, through the 1830s, emissaries from such western trail breakers often visited their kin in Ohio, Illinois, and Indiana, soliciting new recruits and allies.[84] The Lake Superior Chippewa, and other bark canoe-using foragers of the north, had no such experiences, technological capacity, relationships, or inclinations.

There were some few exceptions to this general dislocation and westward resettlement of the prairie tribes. These included some hundreds of Indiana Miami and fewer Michigan Potawatomi who were allowed, by negotiated treaty right, to remain on small parcels in their old environments.[85] Then there were the many who escaped the full consequences of American policy by resettling in British territory. These included numerous horse-nomadic Potawatomi, Ohio Ottawa, and others who settled on the Ontario Peninsula. Making appropriate ecological choices, these voluntary emigrants selected locations south of the Canadian Shield region, in habitats and a climate like those familiar to them. These immigrants studiously avoided British efforts to concentrate on the—to them—barren landscape of Manitoulin Island, further demonstrating the significance of both environmental adaptations and the capacity of Old Northwest Indians to bend the policies of powerful states to their own wants and ends.[86]

More recently than Foreman, Prucha, stressing the extensive prior moves of the Old Northwest's native peoples, concluded that "the emigration of these tribes in the Jacksonian era was part of their migration history.[87] Such an interpretation places the most charitable interpretation conceivable on this American policy, but it does not distinguish one type of migration from another; neither does it look far beneath the surface appearances of events. Such an interpretation is rather like concluding that the experience of Japanese-Americans between 1942 and 1946 may be adequately explained as part of their prior migration history as well.

In a larger historical perspective, none of the Great Lakes-Ohio Valley Indian societies had ever experienced a program quite like the American removal policy as arranged and conducted in the years after 1825. Some, such as the Ontario Iroquoian and Michigan's Algonquian horticultural tribes, during the second half of the seventeenth century had been refugees, fleeing the ravages of war, pestilence, and starvation. Many had sometimes responded to the incentives offered by French or British traders and officials in selecting sites for new settlements. For more, including the Chippewa, their earlier migrations were in response to internal stresses such as population increase, intra-community conflict, resource depletion, or a particularly successful adaptation to new technologies and economic opportunities. Such relocations were generally voluntary, even if encouraged by inducements from European colonial officials, not forced. None of the Indian communities in this region had, until the mid-1820s, collided with a rapidly expanding nation-state bent on fueling its own internal development by the wholesale expropriation of resources and dispossession and dislocation of native inhabitants. The fact that in some instances the goals of particular Old Northwest Indian communities converged with the policies of the United States does not distract from this conclusion. It demonstrates merely that these Indians were adaptable enough to hunt out new opportunities in an unmapped thicket of adversity.

"Settlement pressure" is the most popular, widespread and persistent explanation of the timing or the sequence of efforts at implementing the removal policy.[88] However, as a single-factor explanation this will do neither for the examples of the Chippewa and neighboring foraging bands nor for Old Northwest Indians generally. For at the moment the four American officials conceived their plan to deceive and dislodge the Lake Superior Chippewa, there were few or no Americans "pressing" on their lands. Nor were there many for decades thereafter. Indeed, as witnessed, these Indians found many staunch supporters among the small populations of neighboring citizens. Similarly, had the density of neighboring American population been the major cause of removals, then the perennially reluctant Wyandot of northwest Ohio would have been forcibly transported west at least a decade before their 1843 capitulation and resettlement. "Settlement pressure," perhaps phrased better as significant competition between Americans and Indians for the latter's environmental resources, helps explain how and when Indians were pressured to cede land. By itself it does not explain the drive to move them to distant locations.

Recognizing this distinction—between the acquisition of Indian land and their planned resettlement in distant places—also requires distinguishing the manifest from the less well-recognized functions of the removal policy after 1825. Doing so helps us better understand not only this extraordinary Chippewa case, but efforts to implement this policy among other Old Northwest Indians generally. For decades before 1825, the overt business of acquiring Indian rights to occupy and use the resources of land had been commonly accomplished without necessarily demanding or forcing resettlement in remote locations, certainly not so to an area officially demarked as an exclusive "Indian Territory." Frequently, this was achieved by acquisition of most or nearly all of an Indian society's land, leaving them to concentrate on the remaining parcels of their old estates. Indeed, this was the explicit intention spelled out in the Chippewa's 1837 treaty, not the requirement that they resettle in the west. Moreover, when this planned resettlement policy was finally succeeded by its replacement (the reservation policy), substantial populations of near or entirely landless Indians remained in Michigan and Wisconsin, with smaller groups in Ohio and Indiana, as well as throughout the eastern United States. This did not cause an appreciable slowing of the populating or economic development of these regions. Before and after the years when a comprehensive, nationwide removal policy was in effect, indeed, even between 1825 and the early 1850s, Americans pressing on Indian environments acquired titles to and control of most Indian land without demanding resettlement in a designated all-Indian Territory.

The Chippewa's experiences between 1842 and 1852 forces our attention to a different issue, the understory of the drive to relocate Indians in the west, and to additional conclusions. Whatever the much idealized rationalizations of the Jefferson, Monroe, Adams, and Jackson administrations about the goals of Indian removal, well before 1842—and especially so before the disastrous winter of 1850–1851—the transportation and resettlement of eastern Indians under the ideological guise of benevolent public policy had acquired an institutional life of its own. In the business of collecting, uprooting, transporting, and subsisting Indians, numerous public officials and private citizens discovered incentives and rewards. Removing Indians was often made to serve neither the declared wants, the assessed needs or the passions of neighboring citizens, nor the long range values of a nation. It served, rather, the imperatives of the American state and specifically the narrow political-economic patronage concerns of whatever administration was in power.

In the instance of the abortive effort to dislodge and to resettle the Lake Superior Chippewa, we witness a national patronage system gone awry. Secretary of the Interior Ewing, Commissioner of Indian Affairs Brown, Territorial Governor Ramsey, and the unusually eager and ambitious Sub-Agent Watrous, each from his own distinctive concerns, each with his own network of patrons and henchmen to serve or to satisfy, were directly responsible for arranging this affair. Each bent a near obsolete public policy to his personal career interests and political obligations.[89] Certainly, the consequences of their decisions were exacerbated by legislative chance and environmental accident. Nonetheless the Chippewa's death march was directly caused, to borrow James MacGregor Burns' illuminating phrase, by the self-interested operations of several of those "little circles of influence" that have plagued American life for two centuries.[90] Sub-Agent Watrous did not have to cause the actual permanent relocation of the Chippewa to achieve his personal or his political goals; he had only to seem to do so. Being able to claim a large increase in the Indians under his jurisdiction, he was successful in obtaining an upgrading of the status of his post to a full agency, a promotion to agent, the doubling of his salary, and whatever gratuities grateful St. Paul contractors and Sandy Lake traders may have delivered into his hands.

But what did these Chippewa accomplish for themselves by effectively blocking the efforts of American officials to treat them as an exploitable natural resource? The late Homer G. Barnett has noted that "Dispossession of land and its equivalent, migration, requires adaptation if a group is to survive."[91] The Lake Superior Chippewa, by the terms of the treaties of 1837 and 1842, experienced the loss of ownership of the habitats they had conquered a century earlier, although they skillfully avoided total eviction from these lands. Nonetheless, although they escaped forced emigration, they, too, had to adapt, for their social and physical environments did not remain constant. For decades they were able to apply old knowledge and skills to obtain the essentials for their lives, ranging over familiar terrain, still little settled by Americans, exploiting known sources of food and raw material, while also adjusting themselves to the changing circumstances brought by booming timber and mining industries, and by their status as dependent wards of the federal government.

It was twenty years before all the reservations granted in the 1854 treaty were selected and surveyed, at which moment American settlements had advanced to the point where the federal government at last required the Wisconsin Chippewa to settle on and to extract their subsistence from within these confined spaces. It was in the mid-1870s that the first clear evidence of cultural disintegration appeared in the form of a revitalization movement, the Dream Dance, a missionary-spread new religion, which sought through collective application of supernatural power to defeat American economic and political ascendancy. A full century later, the legal heirs and political successors to the old Chippewa bands turned to the federal courts for a different type of aid, seeking to recover rights allegedly granted to their ancestors by treaty. Employing quite different premises and tactics than in earlier years, the modern Chippewa have met with somewhat greater success. By the later 1980s, they were truly experiencing intensive "settlement pressure," that is, competition for scarce natural resources with their neighbors. The consequences of this latest engagement between Chippewa, American neighbor, and the federal patronage system will be a task for some future scholar to describe, assess, and explain.[92]

Endnotes

[1] This essay reports some findings of the Old Northwest Indian Removal Project, which was supported by a research grant from the National Endowment of the Humanities. The author is indebted to numerous readers of earlier drafts for their aid and useful suggestions, especially Victor Barnouw, Tom Biolsi, John Clark, Faye Clifton, Conrad Heidenreich, Michael Green, Jeanne Kay, Robert Kvasnicka, James McClurken, Joseph Manzo, Bruce Trigger and Richard White; and also Paul Haas, John D. Haeger, and Paul Prucha. In the interests of saving space, citations for this essay have been much abbreviated. A full bibliography is contained in the author's *The Voight Decision and Wisconsin Chippewa Treaty Rights: A Critical Bibliography* (Institute for the Development of Indian Law, forthcoming); and in the archives of the Old Northwest Indian Removal Project.

[2] The nomenclature, "Lake Superior Chippewa," came into use only during negotiations for the Treaty of 1854 at the insistence of the Wisconsin and Upper Peninsula of Michigan bands, who wished to sever all relationships with the bands on the Upper Mississippi River. See, R. Ritzenthaler, "Southwestern Chippewa," in B. G. Trigger, ed., *Handbook of North American Indians,* Vol. 15, *Northeast* (Smithsonian Institution, 1978), 743–59.

[3] The incident is mentioned in a few older state and regional histories such as J. N. Davidson's, *In Unnamed Wisconsin* (Milwaukee 1895), 168; and is briefly discussed in V. Barnouw's *Acculturation and Personality Among the Wisconsin Chippewa* (American Anthropological Association Memoir No. 72, 1950), 37, 59. Such descriptions are based on other secondary and scanty primary sources, principally the Rev. J. H. Pitezel's eyewitness account in *Lights and Shades of Missionary Life* (Cincinnati, 1860), 298. E. J. Danziger, in his *The Chippewas of Lake Superior* (University of Oklahoma Press, 1978), 88, and his "They Would Not be Moved: The Chippewa Treaty of 1854," *Minnesota History,* 43 (1973), 178, touches the episode in passing. William C. Haygood's editorial comments, accompanying publication of excerpts from Benjamin J. Armstrong's reminiscences in his old age, attempted a sketchy assessment of the incident, but these remarks are not well informed. See, "Reminiscences of Life Among the Chippewa," *Wisconsin Magazine of History,* 4 Parts, 55: 175–96, 287–309; & 56: 37–58, 140–61. In the extensive interviewing preceding his *Wisconsin Chippewa Myths and Tales and Their Relation to Chippewa Life* (University of Wisconsin Press, 1977), Barnouw found no oral traditions concerning the events (Barnouw to Clifton, Personal Communication, 1985). Nor are there any such folk memories recorded in the major 20th-Century collections of Chippewa oral traditions, such as the Charles Brown Papers, Col. HB, State Historical Society of Wisconsin, or the U. S. Works Progress Administration's Chippewa Historical Project Records, Microfilm 532, State Historical Society of Wisconsin. The last recorded Chippewa mention of this episode dates to 1864, when the Lake Superior chiefs assembled to record their memories of treaty dealings with the United States. See, G. P. Warren, "Statement of Treaties between the Chippewa Indians and the United States, from 1825–1864, from the Chippewa Standpoint," File 1864, Guide 714 (State Historical Society of Wisconsin).

[4] The cases include, in Wisconsin—the Win-

nebago, Menomini, Potawatomi communities north of Milwaukee, Chippewa of Lake Superior, Mdewakonton Dakota, and the Emigrant New York Indians (Oneida, Stockbridge-Munsee, and the Brotherton); in Ohio—five groups; in Indiana—two groups; in Illinois—three groups; in Michigan—six groups; and from Ontario—two small groups, the Moravian Delaware and Anderdon Hurons.

[5] For the Indiana Potawatomi episode, see J. A. Clifton, *The Prairie People: Continuity and Change in Potawatomi Indian Culture* (Lawrence: Regents Press of Kansas, 1977), 270–72, 296–99; and, R. A. Trennert, Jr., "A Trader's Role in the Potawatomi Removal from Indiana: The Case of George W. Ewing," *The Old Northwest,* 4 (1978), 3–24. The best overview of the Winnebago case is N. O. Lurie, "Winnebago," in, Trigger, *Handbook . . . Northeast,* 690–707. For the Sauk and Fox case see A. F. C. Wallace "Prelude to Disaster," which is lodged amidst Ellen M. Whitney's near comprehensive collection of documents bearing on that episode, *Collections of the Illinois State Historical Library,* 35 (1970).

[6] Recent historical studies of Indian removal exhibit a striking bias as regards commercial "motives" in Indian removal. In his overview of Old Northwest removal, for instance, F. P. Prucha devotes a full section to this topic without once mentioning the involvement and interests of Protestant and Catholic missionaries in implementation of the policy in the region. See his, *The Great Father: The United States Government and the American Indians* (University of Nebraska Press, 1984), Vol. 1, 266–69. Compare, G. A. Schultz, *An Indian Canaan: Isaac McCoy and the Vision of an Indian State* (University of Oklahoma Press, 1972), 123–40.

[7] L. Taliaferro Journals (Minnesota Historical Society), Vol. 10, May 22, 1836; R. W. Meyer, *History of the Santee Sioux* (University of Nebraska Press, 1967), 56–59; H. Hickerson, *Sioux Indians I: Mdewakanton Band of Sioux Indians* (New York: Garland, 1974), 159–205.

[8] *Kinsmen of Another Kind: Dakota-White Relations in the Upper Mississippi Valley, 1650–1862* (University of Nebraska Press, 1984), esp. x–xiii and 150–57.

[9] For background to the Moravian migration, see F. C. Hamil, *The Valley of the Lower Thames, 1640–1850* (University of Toronto Press, 1951), 108–111; C. A. Weslager, *The Delaware Indians: A History* (Rutgers University Press, 1972); and, I. Goddard, "Delaware," in Trigger, *Handbook . . . Northeast,* 213–239. For the background on the Anderdon Hurons, see, C. E. Heidenreich, "Huron," and E. Tooker, "Wyandot," in Trigger, *Handbook . . . Northeast,* 369–88 and 398–406; J. A. Clifton, "Hurons of the West: Migrations and Adaptations of the Ontario Iroquoians, 1650–1704," Research Report, Canadian Ethnology Service, National Museum of Man (Ottawa, 1977); and his, "The Re-emergent Wyandot: A Study in Ethnogenesis on the Detroit River Borderland, 1747," in, K. G. Pryke and L. L. Kulisek, eds., *The Western District* (University of Windsor, 1983); C. G. Klopfenstein, "The Removal of the Wyandots from Ohio," *Ohio Histroical Quarterly,* 66 (1957), 119–136; Robert E. Smith, Jr., "The Clash of Leadership at the Grand Reserve: The Wyandot Sub-Agency and the Methodist Mission, 1820–1824," *Ohio History,* 89 (1980), 181–205; and, E. J. Lajeunesse, C.S.B., *The Windsor Border Region* (Toronto: The Champlain Society, 1960).

[10] M. J. Mochon, "Stockbridge-Munsee Cultural Adaptations: 'Assimilated Indians.' " *Proceedings of the American Philosophical Society* 112 (1968), 182–219.

[11] Rev. J. Vogler to H. R. Schoolcraft, April 10; Schoolcraft to Commissioner of Indian Affairs [COIA] C. A. Harris, April 17 & 28; COIA to Schoolcraft, April 29; Schoolcraft to Vogler, May 8, 1837, in, *Records of the Michigan Superintendency, National Archives Microfilm Series M1* [NAM M[1]], Rolls 37 & 42. Schoolcraft to COIA August 14, and to Gov. H. Dodge, 14 August, 1837, *NAM M1,* Roll 37. Supt. W. Clark to COIA, November 17, 1837, *Office of Indian Affairs, Letters Received, NAM M234,* Roll 756; Harris to Captain E. A. Hitchcock, December 2, 1837, *Office of Indian Affairs, Letters Sent, NAM M21,* Roll 23. R. Cummins to Pilcher, February 4, 1840, *NAM M234,* Roll 301. J. Johnston to COIA T. H. Crawford, March 14, 1842, *NAM M234,* Roll 602; Wyandots of Canada to Sir Charles Bagot, October 10, 1842, *Record Group 10:, Indian Affairs, Red Series—Eastern Canada* (Ottawa, Public Archives of Canada) [*PAC RG10*], Vol. 125. For the joint emigration, See Klopfenstein, "Removal of the Wyandots." Petition of the Hurons to Col. William Jarvis, May 3, 1842, *PAC RG10,* Vol. 125. Wyandot Muster Roll —1843, Entry 301, *Record Group 75, Records*

of the Bureau of Indian Affairs, National Archives and Records Service [*RG75*].

[12] J. A. Clifton, *A Place of Refuge For All Time: Migration of the American Potawatomi Into Upper Canada* (Ottawa: National Museum of Man, 1975); R. F. Bauman, "The Migration of the Ottawa Indians from the Maumee Valley to Walpole Island," *Northwest Ohio Quarterly,* 21 (1949), 86–112.

[13] Gov. Ramsey's report, November 3, 1851, in *Annual Report of the Commissioner of Indian Affairs* (Washington, D.C., 1851) [ARCOIA], 421–22. For sketches of the use of force and of those communities which avoided removal, see the relevant chapters in Trigger, *Handbook . . . Northeast:* see also, Mochon, "Stockbridge-Munsee"; Clifton, *Prairie People* and *The Pokagons, 1683–1983: Catholic Potawatomi of the St. Joseph River Valley* (University Press of America, 1984), Wallace, *Prelude to Disaster;* and, P. K. Ourada, *The Menominee Indians: A History* (University of Oklahoma Press, 1979), 106–123.

[14] H. R. Schoolcraft, *Personal Memoirs of a Residence of Thirty Years with the Indian Tribes on the American Frontiers* (Philadelphia, 1851), 628–29; A. Jackson's Message of March 4, 1837, in, J. D. Richardson, comp., *A Compilation of the Messages and Papers of the Presidents, 1789–1897* (Washington, D.C., 1896–1899), Vol. 2, 541; M. Van Buren's Message of December 5, 1837, in, F. L. Israel, ed., *The State of the Union Messages of the Presidents* (New York, 1966), Vol. 1, 490; *ARCOIA* (1838), 410–411.

[15] Prucha's *The Great Father,* 241–42, provides a useful recent overview of selected features of Old Northwest Removal. The author views the whole process through the eyes of American elites and authorities in Washington, often reflecting but not penetrating their idealized aims and ideological pronouncements, while displaying little understanding of the native peoples and their responses to the policy.

[16] W. Miles, " 'Enamoured with Colonization': Isaac McCoy's Plan of Indian Reform," *The Kansas Historical Quarterly,* 38 (1972), 268–286, has done so.

[17] Treaty with the Sioux, etc., August 19, 1825, 7 U.S. Statutes 272; Treaty with the Chippewa, August 5, 1826, 7 U.S. Statutes 290; and, Treaty with the Chippewa, etc., August 11, 1827, 7 U.S. Statutes 303. Also, Charles J. Kappler, comp. *Indian Treaties: 1778–1883* (reprinted, New York, 1972), 250–55, 268–71; 281–83.

[18] Kappler, *Indian Treaties,* 269.

[19] Flat Mouth's speech, in, Taliaferro to Governor Henry Dodge, September 29, 1836. *NAM M234,* Roll 757. He was referring to the 1836 treaty with the Ottawa and Chippewa of Michigan. For accounts of Lake Superior Chippewa impoverishment in this period, see, G. Franchere to W. Brewster, 14 March 1835, Records of the American Fur Company, Steere Collection, Baylis Public Library, Sault Ste Marie, Michigan, Box 1, Folder 3; Bisheke [Chief Buffalo] to H. R. Schoolcraft, September 8, 1835, *NAM M1,* Roll 72; and, E. A. Brush to Lewis Cass, *NAM M234,* Roll 664.

[20] Secretary of War Lewis Cass to President Van Buren, March 7, 1836, *NAM M21, Roll 18.*

[21] The correspondence, reports, petitions, and memorials concerning their efforts are extensive. For samples, see, S. C. Stambaugh to H. R. Schoolcraft, June 8, 1836, *NAM M1,* Roll 72; COIA C. A. Harris to Governor Dodge, October 15, 1836, *NAM M21,* Roll 20; and, Bailey to COIA E. Herring, June 18, 1836, *NAM M234,* Roll 422.

[22] COIA Harris to A. Bailey, July 15, 1836, *NAM M21,* Roll 19; Hitchcock to Harris, March 30, 1837, *NAM M234,* Roll 751; Taliaferro to Dodge, 30 January, 24 July, and August 2, 1837, *NAM M234,* Roll 758; and, Dodge to Harris, August 15, 1837, *NAM M234,* Roll 758. Major Hitchcock, a regular Army officer, was disbursing agent at the St. Louis Indian Superintendency. The antagonism of some Chippewa to certain traders was real. In December, 1836 a party of Chippewa murdered William Aitken, Jr., the son of a prominent trader by an Indian woman, one of the rare acts of violence by these Chippewa against Americans.

[23] Identified as Royce Area 242, Fig. 1.

[24] COIA Harris to Dodge and General William Smith, May 13, 1837, *NAM M21,* Roll 21. General Smith did not arrive to participate in the treaty negotiations. Earlier, when Secretary of War Cass issued orders for removal treaties with the Winnebago, Menomini, and Emigrant New York Indians, he explicitly excluded the interior Wisconsin Chippewa. See, Cass to Dodge, July 7, 1836, *'NAM M21,* Roll 19.

[25] The first sub-agent at La Pointe, Daniel P. Bushnell, was appointed by Governor Dodge in November, 1836, but was not confirmed until the following April. Edward E. Hill, *The Office of Indian Affairs, 1824–1880: Historical Sketches* (New York, 1974), 88.

[26] Edward D. Neill, "Occurences in and

Around Fort Snelling, from 1819 to 1840," *Minnesota Historical Society Collections,* Vol. 2, 131; William T. Boutwell, "Journel," July 5, 1837, in, *Boutwell Papers.* Col. A.B. 781, Minnesota Historical Society; and, "D. P. Bushell's Report," in, *ARCOIA,* (1838), 467–68.

[27] 1837 Treaty Journal, encl. in Van Antwerp to COIA, September 30, 1837, *Documents Relating to the Negotiation of Ratified and Unratified Treaties, with Various Indian Tribes, 1801–1869, NAM T494,* Roll 3; Warren, "Statement of Treaties." Also see, Hill, *The Office of Indian Affairs,* 90–91, 160–61.

[28] Both came from villages outside the area being ceded. *Magegabow* was a war chief from Leech Lake, *Bugonageshig* an extraordinariiy ambitious upstart village leader from Gull Lake. See, James G. E. Smith, *Leadership Among the Southwestern Ojibwa,* Publications in Ethnology No. 7, National Museum of Man (Ottawa, 1973).

[29] See Dodge's marginal notes on p. 21 of the treaty journal to this effect.

[30] This they subsequently did. See, Warren, "Statement of Treaties"; and, Obishkawzaugee's Speech, September 12, 1869, *NAM M234,* Roll 394.

[31] Boutwell to Rev. David Green, August 17, 1837, *American Board of Commissioners for Foreign Missions Papers* (Minnesota Historical Society—Transcripts of Originals in Houghton Library, Harvard University) [ABCFMPMNHS], Box 2.

[32] Rev. Frederick Ayer to President Martin Van Buren, September 30, 1837; Gov. Dodge to COIA, February 17, 1838, *NAM M234,* Roll 387.

[33] J. Schoolcraft to H. R. Schoolcraft, November 21 and December 1, 1837, *NAM M1,* Roll 45.

[34] B. F. Baker to COIA, January 9, 1838, *NAM M234,* Roll 758; Dodge to COIA, July 6, 1838, in, C. F. Carter and J. P. Bloom, eds., *Territorial Papers of the United States* (Washington, D.C., 1934–1969) [TPUS], Vol. 17, 1029–31; and, COIA to Dodge, July 26, 1838, *NAM M21,* Roll 24; A. Brunson to R. Stuart, July 20, 1843, *NAM M1,* Roll 55.

[35] A. W. Schorger, "The White-Tailed Deer in Early Wisconsin," *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters,* 42 (1953), 197–247; and, H. Hickerson, *The Southwestern Chippewa: An Ethnohistorical Study,* American Anthropological Association Memoir No. 92 (1962), 12–27. Gary C. Anderson in, *Little Crow: Spokesman for the Sioux* (Minnesota Historical Society Press, 1986), p. 57, points out that by 1851 Medwakanton Dakota were again hunting deer in the St. Croix valley, then "more abundant than in previous seasons," near areas cut-over by timber men.

[36] D. P. Bushnell to Dodge, February 12, 1839, *TPUS* 27:1196; and, H. Dodge to Secretary of War, April 25, 1841, *NAM M234,* Roll 759.

[37] Treaty with the Chippewa, October 4, 1842, 7 U. S. Statutes 591; Kappler, *Indian Treaties,* 542–45. The lands involved are identified as Royce Area 261, Fig. 1.

[38] For a discussion of "half-breeds," "mixed-bloods," and other cultural marginals, see, James A. Clifton, *Being and Becoming Indian: Biographic Studies of North American Frontiers* (Chicago, The Dorsey Press, in press).

[39] Kappler, *Indian Treaties,* 542–45. Official Documentation for this treaty is scanty, since Stuart kept no journal and delivered no written report on his deliberations. However, the Rev. L. H. Wheeler independently prepared a journal, including a particularly full eye-witness description of events, which he sent to his superior, David Greene, May 3, 1843, ABCFMP-MNHS, Box 3. Moreover, because of the controversy aroused, there is an unusual amount of supplementary reporting on these negotiations, for example in Warren, "Statement of Treaties," and from other Chippewa and American participants, such as A. Brunson to J. D. Doty, January 6, 1843, NAM M1, Roll 54.

[40] P. Holland, *The Philosophie, Commonlie Called, The Morals of Plutarchus* (London, 1603), 1237.

[41] COIA Crawford to Stuart, August 1, 1842, *NAM M1,* Roll 53.

[42] A. Brunson, *A Western Pioneer* (Cincinnati, 1872), Vol. 2, 165–69; Stuart to COIA, October 24 and November 19, 1842, *NAM M1,* Roll 39; *ARCOIA* 1842, 401–402; A. Brunson to Gov. J. D. Doty, January 8, 1843 (encl., letter from Chief Buffalo to L. Warren, October 29, 1842 & speech of White Crow, December 18, 1842), *NAM M234,* Roll 388; and the Rev. Wheeler's account of the negotiations, cited above.

[43] Stuart, "Substance of Talk to the Chippewa," September 29, 1842 (a communication reconstructed later and enclosed in Stuart to COIA, March 29, 1844), *NAM M234,* Roll 389. Cyrus Mendenhall to COIA, January 6, 1851; Rev. L. H. Wheeler, "Journal of 1842 Treaty," in, Wheeler to Rev. David Greene, May 3, 1843, ABCFMP-MNHS, Box 3; Stuart

to Rev. Greene, December 8, 1842; Chief Martin to Rev. A. Brunson, encl. in Brunson to COIA, to Gov. Doty, and to Secy. War Spencer, January 8, 1843, *NAM M234,* Roll 388; Warren, "Statement of Treaties" (section on 1842 treaty).

[44] In the memoir dictated in his old age, B. G. Armstrong claimed Stuart had promised that the Chippewa could remain on their lands so long as they remained peaceful. There is no independent suggestion of the truth of this assertion—that continued occupancy and use rights were contingent on good behavior as there is little support for other such claims in Armstrong's reminiscences. Americans in the era would have classified any such misbehavior as "depredations," individual acts, which under the Trade and Intercourse Act of 1834 and Chippewa treaties required the punishment of the individuals concerned, not the tribe collectively. Armstrong, a self proclaimed "friend of the Chippewa," was actually an inconsequential figure on this frontier, who in his later years much inflated his role as mover and shaker among the Chippewa and in the corridors of power. He is barely mentioned in contemporary public and private sources, where some of his depictions are contradicted and others unsupported by various eye-witness participants. The original is, *Early Life Among the Indians* (Ashland, Wisconsin, 1892); edited excerpts republished as Armstrong, *Reminiscences.*

[45] Kappler, *Indian Treaties,* 542–45; Brunson to Doty, July 19, 1842, *NAM M234,* Roll 388; Stuart to D. Greene, December 8, 1842, *ABCFMP-MNHS,* Box. 3. For background on mining developments in the area, see R. J. Hybels, "The Lake Superior Copper Fever," *Michigan History,* 23 (1950), 97–119 & 309–26.

[46] Doty to Secretary of War, November 17, 1841; H. L. Dousman and H. H. Sibley to Secretary of War, February 18, 1841; and L. Warren to Doty, October 2, 1841; in, *NAM M234,* Roll 388.

[47] Identified as Royce Area 332, Fig. 1.

[48] Doty to COIA, April 5, 1843, *NAM M234,* Roll 517; and, Stuart to COIA, June 2, 1843, *NAM M1,* Roll 39.

[49] Doty to COIA, April 5, 1843, *NAM M234* Roll 427. COIA to Stuart, 13 May, 1843, *NAM M1* Roll 54. Stuart to COIA, 2 June, 1843 & 29 March, 1844, *NAM M1* Roll 39. COIA W. Medill to I. A. Verplanck & Charles Mix, June 4, 1847, *NAM M21* Roll 39. COIA to Gov. Dodge, August 2 and 16, 1847, *NAM M21* Roll 40. C. Borup to W. A. Richmond, August 31, 1847, *NAM M1* Roll 61. COIA to G. Copway, December 14, 1847, *NAM M21* Roll 40; and, *ARCOIA* 1847, 8–9.

[50] COIA Medill to Dodge, October 31, 1846; and to Henry M. Rice, October 31, 1846, *NAM M21* Roll 38. Medill to Dodge, August 2, 1847; and to Brig. Gen. R. Jones, December 6, 1847, *NAM M21* Roll 40.

[51] There is no hint of such a commitment in the records of this treaty negotiation or in the Chippewa complaints about these immediately thereafter. The 1848 assertion was probably an example of Chippewa negotiating style, although they certainly wanted reservations.

[52] They were imitating the Indians of Michigan's lower peninsula who had used this same tactic successfully more than a decade earlier. See, J. McClurken, "Strangers in Their Own Land," *The Grand River Valley Review* (1985), Vol. 6, 2–26; and J. A. Clifton, "Leopold Pokagon: Transformative Leadership on the St. Joseph River Frontier," *Michigan History* (1985), Vol. 69, 16–23.

[53] Medill to R. McClelland, March 3, 1848, *NAM M21* Roll 40; G. Johnston to H. R. Schoolcraft, June 28 & August 18, 1848, *NAM M234* Roll 771; Medill to J. E. Fletcher, c/o T. Harvey, August 17, 1848, *NAM M21* Roll 41; Petition of Lake Superior Chippewa Head Chiefs, February 5, 1849, House Misc. Doc. 36, 30–2 [CS 544]; Delegation of Chippewa Head Chiefs to President, February 5, 1849, *NAM M234* Roll 390; Medill to Livermore, August 22, 1848 & February 12, 1849, *NAM M21* Roll 41. S. Hall to A. Hall, March 28, 1849, *Northwest Mission Papers* [*NWMP-UMD*] Box 1, Folder 1, University of Minnesota—Duluth; Pitezel Journal, July 9, 1849, *J. H. Pitezel Papers* [*JPP-CHL*], Clarke Historical Library, Central Michigan University. "Chippewas of L'ance," *Lake Superior News & Mining Journal* [*LSN&MJ*], June 12, 1850.

[54] "Removal of the Payments to Sandy Lake," Journal V, 1851, *JPP-CHL.*

[55] R. A. Trennert, "Orlando Brown," in, R. M. Kvasnicka and H. J. Viola, eds., *The Commissioners of Indian Affairs, 1824–1977* (University of Nebraska Press, 1979), 41–48.

[56] Relocating the Chippewa would have meant the loss of the only females then available to loggers and miners. Indeed, the infrequent conflicts that erupted between Americans and Chippewa were occasioned by the former trying to gain sexual access to Chippewa women. See, R. N. Current, *The*

History of Wisconsin: Civil War Era, 1848–1873, (State Historical Society of Wisconsin, 1976), Vol. 2, 154.

[57] H. M. White, *Guide to the Microfilm Edition of the Alexander Ramsey Papers and Records* (Minnesota Historical Society), 16–18; and, Current, *History of Wisconsin,* Vol. 2, 197–205. The Lake Superior Chippewa's annual monetary value that year consisted of $22,000, and $44,200 in goods and services, plus the salaries of employees of the Indian Department. All cash payable in specie—gold and silver. This was a considerable resource for a struggling, cash-poor new Territory. See "Omnibus Appropriation Bill," House Miscellaneous Document 57, November 12, 1850, 31-1, Vol. 2, p. 61 [CS 582].

[58] Presidential Order, February 6, 1850, in C. J. Kappler, *Indian Affairs: Laws and Treaties,* 5 Vols. (Washington, D.C., 1904–1941), Vol. 5: 663; Brown to Ramsey, February 6, 1850, *NAM M21* Roll 43; Ramsey to Livermore, March 4; and, Livermore to Ramsey, March 21, 1850 *NAM M234* Roll 428; Secretary of State, *Legislative Manual of the State of Wisconsin,* 9th Ed. (Madison, 1870), p. 209.

[59] Brown to Watrous, April 22, 1850, *NAM M21* Roll 43; "John S. Watrous File," in, Minnesota Territory, Appointments Division, Secretary's Files, *National Archives Record Group 48, Interior Department Appointment Papers* [*RG48*].

[60] Rev. Wheeler to Ely, June 19 & July 22, 1850; Rev. Hall to Ely, July 16, 1850; in, *E. F. Ely Papers* [*EFEJ-SHSW*], State Historical Society of Wisconsin, Vol. 3.

[61] S. B. Treat to COIA Lea, May 12, 1852, *ABCFMP-MNHS,* Box 6.

[62] J. N. Davidson, "Missions on Chequamegon Bay," *Collections of the Wisconsin State Historical Society,* Vol. 12, 434–52; *Milwaukee Weekly Wisconsin,* June 5, 1850; J. P. Durban to Secretary of the Interior, October 3, 1850, *NAM M234,* Roll 767; D. King, *et al.,* to D. Atkins, July 15, 1850, *NAM M234,* Roll 771; S. Hall to Treat, 28 March 1850, *ABCFMP-MNHS,* Box 5; Hall to Ramsey, 28 March 1850, *NAM M234,* Roll 168; H. Hall to L. D. Mudgett, March 13, 1850, *NWMP-UMD,* Box 1. Hall to Treat, October 7, 1852 and May 17, 1853, *ABCFMP-MNHS,* Box 6.

[63] Mendenhall to Lea, January 6, 1851, *NAM M234* Roll 767; Congressman J. R. Giddings to President, July 30, 1850, w/ encl., Petition from Citizens of Lake Superior South Shore, *NAM M234* Roll 390; *LSN&MJ,* June 5 and 12, 1850; *Milwaukee Weekly Wisconsin,* June 5 and July 3, 1850; J. P. Durban to Secretary of the Interior, October 3, 1850, *NAM M234* Roll 767. D. Aitken to Lea, August 26, 1850, *NAM M234* Roll 771. "Important Movement Among the Chippewa," and, "Chippewa Delegation," *Detroit Free Press,* November 28, 1848 and February 19, 1849.

[64] *LSN&MJ,* June 5, 1850; Pitezel Journal, Vol. 5, June 3, 1850, *JHPP-CHL;* L. H. Wheeler to E. F. Ely, July 22, 1850, E. F. Ely Papers [*EFEP-MNHS*], Minnesota Historical Society, Vol. 3; "Correspondence from J. Bowron," *Boston Daily Journal,* September 14, 1850; Watrous to COIA, December 31, 1850, *NAM M234,* Roll 767; Watrous to Ramsey, November 14, 1850. *NAM M234,* Roll 767.

[65] Brown to Ramsey, March 26, 1850; Watrous was handed his commission in Washington a month later—Brown to Watrous, April 22; *NAM M21,* Roll 43; "Indians to be Removed," June 1, and "From the Lake Superior Journal," June 27, 1850, *Detroit Free Press.*

[66] Pitezel, "President Conditions and Prospects of the Missions," Journal, Vol. 5, July, 1850, *JHPP-CHL;* Hall to Ely, February 24, 1851, *EFEP-MNHS,* Vol. 3; Pitezel, *Lights and Shades,* 247; Hall to Ely, February 24, 1850, Vol. 3, *EFEP-SHSW; Annual Report of the Missionary Society of the Methodist Episcopal Church* [*ARMS-MES*], 1850, 70–71.

[67] Pitezel, "Journal," Vol. 5 (1851), *JHPP-CHL;* Armstrong "Reminiscences," 290–92; W. Bartlett, *History, Tradition, and Adventure in the Chippewa Valley* (Chippewa Falls, Wisconsin, 1929), 67–70, 119–120; Watrous to Ramsey, n.d. [c. December 12], 1850. *NAM M234,* Roll 767.

[68] Bartlett. *History, Traditions,* 69; J. E. Fletcher to Superintendent T. H. Harvey, November 14, 1850, *NAM234,* Roll 760; Pitezel, *Lights and Shades, 298–99; Watrous to Ramsey, November 14; n.d.* [c. December 12]; & December 30, 1850; in *NAM M234* Roll 767. Chippewa Annuity Pay Rolls, 1850, Item 186, Annuity Pay Lists. *RG 75.*

[69] Pitezel, Journal, Vol. 5 *JHPP-CHL* (1851); E. D. Neill, "History of the Ojibways," *Collections of the Minnesota Historical Society,* 5 (1885), 500; Armstrong, "Reminiscences," 289–92; Hall to Ely, December 25, 1850, *EEJ-SHSW,* Vol. 3.

[70] Watrous to Ramsey, November 13 & 14;

n.d. [c. December 12]; & December 30, 1850; in *NAM M234* Roll 767; Ramsey to COIA; December, 1850; in *NAM M234* Roll 767; *HMD 57,* 61.

[71] Ramsey to COIA, November 14, encl., Watrous to Ramsey, November 12, 1850, *NAM M234,* Roll 767; Annuity Records, 20607–#798, Sandy Lake Sub-Agency, December 2, 1850, *RG 75.*

[72] Chippewa Chiefs [of interior] to President Fillmore, [c. November], 1852; and, Chief Buffalo, *et al.,* [of lake shore] to COIA Lea, November 6, 1851; in, *NAM M234,* Roll 149; Watrous to Ramsey, December 10, 1850; W. W. Warren to Ramsey, January 21, 1851; Ramsey to COIA Lea, March 27, 1851; all in *NAM M234* Roll 747. Hall to Treat, December 30, 1850, *ABCFMP-MNHS,* Box 5. H. Hall to L. Burbank, January 14, 1861, *NWMP-UMD,* Box 1, Folder 41; and, Pitezel, Journal Vol. 5, July, 1851, *JPP-CHL.*

[73] Chippewa Chiefs to President Fillmore, and Chief Buffalo, *et al.,* to COIA Lea, cited above. Watrous to Ramsey, December 10, 1850; W. W. Warren to Ramsey, January 21, 1851; Ramsey to Lea, March 27, 1851; all in *NAM M234* Roll 747. "Lake Superior and Mississippi bands Chippewa Chiefs, Sandy Lake Sub-agency, December 2, 1850, Receipt for Provisions," Annuity Records, Item 20607–#798, *RG 75.* Hall to Treat, December 30, 1850, *ABCFMP-MNHS,* Box 5; Hall to L. Burbank, January 14, 1851, *NWMP-UMD,* Box 1, Folder 41. Pitezel, "Journal," Vol. 5, July, 1851, *JPP-CHL.*

[74] Lea to Secretary of the Interior, June 3, 1851, Report Books of the Office of Indian Affairs, *NAM M348,* Roll 8. C. K. Smith (Secretary, Minnesota Territory) to Lea, February 7, 1851; and, Petition of Wisconsin Assembly, February 18, 1851; both in *NAM M234* Roll 767. *LSN&MJ,* June 11 & 18, July 28, & September 27, 1851. P. Greely (Collector of the Customs, Boston), w/encl., Boston news clipping, to Secretary of the Treasury, August 23, 1851, *NAM M234* Roll 149. Watrous to COIA, July, 1851, *NAM M234* Roll 149.

[75] Watrous to Ramsey, September 22, 1851, *NAM M234* Roll 149. See also, COIA to Secretary of the Interior, June 3, 1851, *NAM M348,* Roll 8; Lea to Watrous, 25 August, 1851, *NAM M21* Roll 45; and, Treat to Hall, September 24, 1851, *ABCFMP-MNHS* Box 5.

[76] Watrous survived the charges against him of dereliction in public duty. His patrons in Washington and Minnesota defended him until mid-1852, when he fell under a graver suspicion, of infidelity in political character. It was first claimed, then confirmed, that Watrous had been masquerading under false party colors. As a Minnesota competitor put it on February 28, 1853, he came "on to the Mississippi a rampant Whig. He now pretends to be a strong Democrat." It was an appropriate time for Watrous to adopt this fresh party hue, for Franklin Pierce was to be inaugurated three days later. While this switch did not save him his position as Indian Agent under the new Democratic administration, it did ease the way for his later success in Minnesota. He settled in the Fond du Lac area where he became the Register of the U. S. Land Office, and, after Minnesota's statehood, the first—Democratic—Speaker of the Minnesota Assembly. As he had anticipated in 1850, a tour as Indian Agent was a profitable thing for a young man on this frontier, both financially and as a means of career advancement. See, E. Whittsley to President Fillmore, April 17, 1852, *NAM M234* Roll 149; and November 16, 1852, Roll 767. J. R. Carey, "History of Duluth, and of St. Louis County to the Year 1870," *Minnesota Historical Collections* Vol. 9, 250. S. B. Olmstead to S. B. Lowry, February 28, 1853, in, "John Watrous File," *RG 48.*

[77] Watrous to Lea, June 7, 1852, *NM M234,* Roll 149; Citizens of Lake Superior Petition to President Filmore, June 4, 1852, *NAM M234,* Roll 149; Chief Buffalo to Ramsey, July 23, 1852, *NAM M234,* Roll 428; B. Armstrong, *Early Life Among the Indians,* 26, 30–31, 101. There is no separate confirmation of Armstrong's claims to personal credit for this success. "Treaty with the Chippewa, 1854," Kappler, *Indian Treaties,* 648–52.

[78] *The Last Trek of the Indians* (University of Chicago Press, 1946), 14–15.

[79] Charles Callender calls this the secondary or lesser configuration of Old Northwest Indian patterns in his, "Great Lakes-Riverine Sociopolitical Organization," in Trigger, *Handbook . . . Northeast,* 610.

[80] James A. Clifton, *A Place of Refuge;* J. McClurken, "Ottawa Adaptive Strategies to Indian Removal," *The Michigan Historical Review* (1986), Vol. 12, 29–57.

[81] Callender refers to this as the dominant configuration in the Old Northwest, "Great Lakes-Riverine," 610.

[82] See, Treaties with the Seneca, Shawnee,

and Ottawa, 1831 in Kappler, *Indian Treaties,* 325–39. Also, Prucha, *Great Father,* Vol. 1, 247–48.

[83] James A. Clifton, "From Bark Canoes to Pony Herds: the Great Lakes Transportation Revolution, 1750–1775," *Henry Ford Museum & Greenfield Village Herald* (Vol. 15, 1986), 12–19.

[84] C. G. Klopfenstein, "The Removal of the Indians from Ohio, 1820–1843," Ph. D. diss., Western Reserve University, 1956, 61–62; J. Johnston to L. Cass, February 3, 1824 and April 14, 1825, *NAM M1,* Rolls 14 and 16; "Wapokonetta Council," *Niles Weekly Register,* June 25, 1825; E. W. Duval to Secretary of War Calhoun, November 28, 1824, *NAM M234,* Roll 60; Actg. Governor R. Crittenden to Calhoun, September 28, 1823, *TPUS,* Vol. 19, 549.

[85] Bert Anson, *The Miami Indians* (University of Oklahoma Press, 1970), 213–33, 266–89; S. J. Raefert, "The Hidden Community: The Miami Indians of Indiana, 1846–1940," Ph. D. diss., University of Delaware; Clifton, *The Pokagons.*

[86] R. F. Bauman, "Kansas, Canada, or Starvation," *Michigan History,* Vol. 36, 287–98; Clifton, *A Place of Refuge.*

[87] See, *Great Father,* Vol. 1, 244; compare, James A. Clifton, "Escape, Evasion, and Eviction: Adaptive Responses of the Indians of the Old Northwest Territory to the Jacksonian Removal Policy of the 1830s," TS, paper read at the Conference on the American Indian and the Jacksonian Era, Middle Tennessee State University (1980), 17–18 (Copy on deposit, D'Arcy McNickle Center, Newberry Library, and Wisconsin State Historical Society).

[88] See, H. H. Tanner, ed., *Atlas of Great Lakes Indian History* (University of Oklahoma Press, 1986), 122–125.

[89] E. Whittsley to President Fillmore, April 17, 1852, *NAM M234* Roll 149; and November 16, 1852, Roll 767. Carey, "History of Duluth," 250.

[90] *The Power to Lead: The Crisis of the American Presidency* (New York, 1984), 122.

[91] *Qualitative Science* (New York, 1983), 203–204.

[92] For the later reservation history, see P. Shifferd, "A Study in Economic Change Among the Chippewa of Northern Wisconsin: 1854–1900," *The Western Canadian Journal of Anthropology* 6–4 (1976); and, Danziger, *The Chippewas,* 91–132.

The Aquatic Macrophyte Community of Black Earth Creek, Wisconsin

Roy Bouchard and John D. Madsen

Abstract. *The aquatic macrophyte community of Black Earth Creek, Wisconsin, was studied in June and July of 1985 and compared to data collected in 1981. Macrophyte distribution was examined by the line intercept method, with macrophyte cover negatively correlated to light reduction by tree canopy. The dominant species in the stream was* Potamogeton crispus. *Other species included* P. pectinatus, P. vaginatus, Elodea canadensis, Ranunculus longirostris, Hypericum boreale *and filamentous algae, namely* Rhizoclonium *sp. Average total cover of all macrophytes was 55.6%. Cover of macrophytes was only slightly lower in 1985 than in 1981, which was thought to be due to random population fluctuations rather than directional change in the community. Macrophyte biomass was estimated at three unshaded stations. Maximum macrophyte biomass was 789 g dw m^{-2}, with no relation found between biomass and the inflow of a sewage treatment plant. Samples of* Potamogeton crispus *and* Rhizoclonium *sp. analyzed for tissue phosphorus indicated that plants are not near limiting concentrations for P; rather, present data indicate that light availability limits the growth of macrophytes in Black Earth Creek. Oxygen mass balance was used to estimate community photosynthesis and respiration, and the macrophyte/epiphyte contribution to community respiration estimated by* in situ *incubations. Macrophyte/epiphyte respiration contributed 47% to 68% of community respiration. The P/R ratio was 0.62, indicating a heterotrophic stream community.*

Aquatic macrophytes are an important component of stream ecosystems, influencing physical, chemical and biological processes. Aquatic macrophytes stabilize the stream substrate, reducing turbidity and erosion. They also increase deposition of suspended solids, further reducing turbidity, and oxygenate the water by means of photosynthesis. Stream channels deepen and current increases between adjacent plant beds, improving habitat diversity. Aquatic macrophytes and attached epiphytic algae provide food and habitat for macroinvertebrates and other small organisms, as well as protection for large fish species. Macrophytes increase stream productivity beyond energy gained by allochthonous inputs. In addition to these benefits, macrophytes provide surface area for microbes, which contribute significantly to many chemical processes in the stream, such as nitrification, respiration, and decomposition.

However, excess growths of macrophytes can also create problems for the stream ecosystem. Bank-to-bank growths of aquatic macrophytes will slow current velocities, causing flooding and siltation. Homogeneous growths of macrophyte species reduce habitat heterogeneity. Most importantly, excessive plant growths create large daily dissolved oxy-

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gen fluctuations. Nighttime respiration may reduce dissolved oxygen to levels that are stressful or lethal to oxygen-sensitive organisms.

Recent concern for Black Earth Creek centered on potential eutrophication and the resultant effect on this highly productive trout stream. Decisions on the management of plants require some assessment of their distribution, abundance, and impact on the stream. With this in mind, we addressed the following:

1. Species and plant distribution in 1981 and 1985 and their relationship to several physical factors.
2. The relationship between tree canopy, light availability, and plant growth.
3. Macrophyte biomass in Black Earth Creek, with sampling above and below a point source of nutrients.
4. The contribution of macrophyte respiration to the oxygen balance of the stream.
5. Potential phosphorus limitation of macrophyte biomass.

Macrophyte Cover

Previous work (Madsen 1982; Madsen and Adams 1985) on Black Earth Creek surveying the plant communities and physical environment in four sections of Black Earth Creek (Segments 1–4, Figures 1 and 2) indicated that light limitation by tree canopy and turbidity are probably the most important factors limiting plant productivity. The relationship between instream plant communities and shading has been extensively studied. Light availability is likely the most important factor limiting plant growth (Dawson and Kern-Hansen 1978; Dawson *et al.* 1978; Krause 1977; Barko *et al.* 1985; Peltier and Welch 1969). The effects of removing the tree canopy were noted by Hunt (1979) in the Little Plover River (Wisconsin), where first year increases in macrophyte cover of more than 200% were seen, with accompanying increases in water temperature and trout production.

Biomass

The actual impacts of macrophytes on the stream environment depend heavily on the amount of plant tissue, or biomass, present in the stream. Methods for estimating plant cover are valuable in allowing rapid quantitative surveys but cannot be used to estimate biomass at higher cover frequencies. Quantification of instream biomass is difficult due to the heterogeneity of such systems and the large number of samples needed to obtain statistically meaningful estimates. Recent work in Badfish Creek, Wisconsin (Madsen 1986), indicated that even short stretches (50–100 m) of relatively homogeneous steam may need sample sizes in excess of 15 to 20 samples.

Respiration and Dissolved Oxygen Modeling

Diel variation in dissolved oxygen levels are caused in part by macrophyte photosynthesis (Ps) and respiration (R) (Kelly *et al.* 1983). Macrophytes are only one oxygen consumer in an aquatic system. Bacteria, algae, macroinvertebrates, and higher fauna all contribute to overall respiratory load (McDonnell 1982). Estimates of reaeration coefficients (K2), Ps, and R for the community may be made by finite difference models without detailing their components. Single station models commonly rely on assumptions such as homogeneity of the study reach for some distance above the sampling point, Ps proportional to light intensity, and constant R and K_2 despite changes in temperature (Mace *et al.* 1984, Owens 1966).

Phosphorus Limitation

Unquantified observations of increased macrophyte growth below the sewage treatment plant in Cross Plains caused Brynildson and Mason (1975) to suggest that P input at that point is responsible. Values reported for total and soluble P for 1985 (WDNR data, unpub.) indicate a substantial input of P due to a point source in the upper watershed. In response to the speculation that phosphorus input to Black Earth Creek may increase macrophyte growth, we analyzed tissue phosphorus from the dominant macrophyte *(Potamogeton crispus)* at several sites to check for limiting tissue P concentrations. In a literature review of nutritional and ecological growth controlling factors, Barko *et al.* (1985) concluded that there are few examples of naturally occuring macrophyte populations exhibiting limitation by phosphorus. Inorganic carbon and physical factors (e.g., light) seem to play a dominant role in limiting aquatic macrophyte growth (Huebert and Gorham 1983; Peltier and Welch 1969).

Work on lake systems (e.g., Carignan 1982; Carignan and Kalff 1979, 1980; Barko and Smart 1981) indicates that sediments provide the bulk of tissue P. Estimates of the sediment contribution to plant tissue phosphorus range from 70 to 100% (Huebert and Gorham 1983). Total removal of P from experimental water columns resulted in unimpeded growth by plants with sufficient sediment nutrients. Mace *et al.* (1984) speculated that the macrophytes in Black Earth Creek utilized sediment P more than water column P, based on a model for other Wisconsin streams.

Literature reports of tissue P in natural populations indicate concentrations ranging from 0.15 to 0.6%. Plants immersed in greatly enriched waters (e.g., Badfish Creek, Dane County, WI) may show concentrations as high as 0.7 to 1.0% P (Madsen 1986). Tissue P levels for all species of plants sampled in Wisconsin by Mace *et al.* (1984) ranged from 0.13 to 0.67%, all of which were above the critical growth level of 0.1% established by Gerloff (1973, 1975).

Methods

Site Description

Black Earth Creek is a highly productive, calcareous stream in western Dane County, Wisconsin (Fig. 1). This limestone stream is classified as a "class-one" trout stream by the Wisconsin Department of Natural Resources (WDNR), indicating that it sustains a population of naturally reproducing trout (Brynildson and Mason 1975). Black Earth Creek is a valuable natural resource to the state, with trout productivity (472 kg ha^{-1} y^{-1}; Brynildson and Mason 1975) nearly as high as the Horokiwi Stream in New Zealand (540 kg ha^{-1} y^{-1}; Allen 1951) and higher than other trout streams studied in the midwest.

Water quality is rated from good to fair, with some water quality degradation related to high concentrations of phosphorus and coliform bacteria (Lathrop and Johnson 1979). Groundwater and artesian spring water maintain low temperatures and high oxygen levels, such as

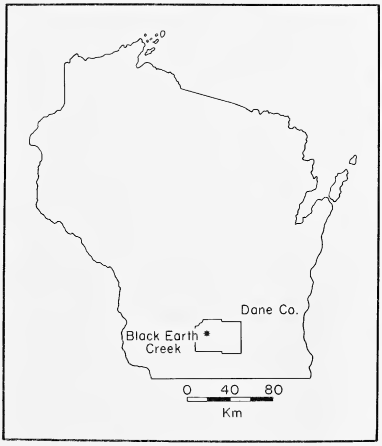

Fig. 1. A map of Wisconsin indicating location of Dane County and Black Earth Creek.

are necessary to support trout and other oxygen-sensitive organisms in Wisconsin (Threinen and Poff 1963).

Black Earth Creek is on the edge of the unglaciated Driftless Area of southwestern Wisconsin. The watershed is largely agricultural (Born 1986). Our study area extends from above the Village of Cross Plains to just above the Town of Black Earth, with seven study sections indicated (Fig. 2). One significant point source of pollution is the Cross Plains Sewage Treatment Plant. However, nonpoint pollution occurs from agricultural activities throughout the watershed as well as urbanization and development in the Village of Cross Plains and the Town of Middleton at the headwaters.

Macrophyte Cover and Physical Environment

During June and July of 1985, four areas previously studied in 1981 were remapped (sections 1–4), along with three additional sections (Fig. 2) to quantify any major changes in macrophyte cover and characterize downstream segments of the creek. Line-intercept methods were consistent with those used in 1981 (Madsen 1982). Once each month, twenty stratified-random transects were sampled in each segment. The transect was placed across the stream, and the occurrence of each macrophyte species in each 1 dm segment recorded. A species found in the 1 dm segment was considered to "cover" that 1 dm segment. Overhead tree canopy was estimated by eye to the nearest 10% at each transect site. Photosynthetically active radiation (PAR) was measured at the stream surface in the center of the channel as well as 1.5 m from each shore using a LiCor quantum meter and probe, with light availability expressed as a percentage of open-field light intensity. Water depth and depth of silt deposits were measured at 1 m intervals, and stream width at each transect. The per-

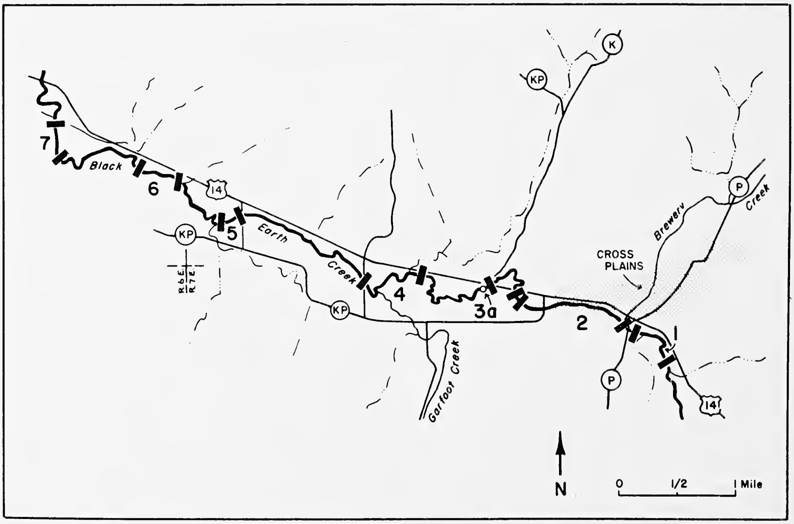

Fig. 2. Map of Black Earth Creek, indicating study sites 1 through 7. Figure reprinted from Water Resources Management Workshop Report (Born 1986).

centage of substrate composed of silt, sand, and gravel at the surface was estimated at each transect.

Biomass

The ability of the stream to support plants was quantified by taking standing crop biomass samples in three representative unshaded areas. Phenological evidence from the literature (Sastroutomo 1981; Kunii 1982) and previous observations on Black Earth Creek (Madsen 1982) suggested plant biomass would peak in early to mid-July. Sampling peak biomass provides a crude estimate of the potential productivity in the stream.

One site within each of three sections (1, 3 and 7) was chosen based on the lack of shade, presence of dense macrophyte growths, and position relative to the sewage treatment plant at Cross Plains. Fifteen stratified random samples were taken from each site. Sites 1 and 7 were 150 m in length; site 3 was 100 m long (Fig. 2). These sites had heterogeneous bottoms of silt over gravel with open channels scoured to bare gravel between dense macrophyte beds. Each sample was harvested from a 0.19 m^2 quadrat at the sediment surface, with inclusion of less than 10% root material. Samples were sorted by dominant species and dried at 70°C. Species identifications and nomenclature follow Fassett (1957).

Respiration and Dissolved Oxygen Modeling

Dissolved oxygen variations of 6–8 mg O_2 l^{-1} observed in the stream over 24-hour periods (WDNR data, unpubl.) prompted a concern for adequate oxygen to sustain sensitive organisms (e.g., trout). The percentage contribution of macrophytes and attached epiphytes to the whole stream respiration of one area of Black Earth Creek was estimated to indicate the role of macrophytes in community oxygen depletion.

A single station model developed by Mark Tusler (WDNR) was applied to Site 1 (Fig. 2). Temperature and dissolved oxygen data (uncorrected probe readings) were obtained from the U. S. Geological Survey (USGS) from the gaging station at Cross Plains (downstream end of Site 1) for June 12–14. Simultaneous temperature and dissolved oxygen measurements were taken at 8 A.M. and 2 P.M. at each end of the study stretch on June 13. Low variation in temperature (less than 0.2°C) and dissolved oxygen (less than 0.1 mg 0_2 l^{-1}) indicated uniformity of the water mass in the stretch, a necessary requirement to satisfy the assumptions of the single station model utilized.

Dark respiration estimates for the dominant macrophytes (*P. crispus* at site 1 and *P. vaginatus* at site 7) were done on June 13 and 14 with a total of 12 replicates for each species. Twenty cm terminal sections of healthy shoots were incubated *in situ* in 300 ml BOD bottles (taped to exclude light) for periods of 2–3.5 hours, along with stream water controls. Dissolved oxygen concentrations were determined by the azide modification of the Winkler method (APHA Standard Methods 1981). Plants were removed from the bottles immediately after acidification and dried to constant weight at 70°C. Subsamples were used to determine total ash content at 550°C. No attempt was made to remove epiphytes prior to incubation because these contribute directly to respiration as part of the macrophyte-epiphyte complex in the stream.

Phosphorus Limitation

Following the rationale of Gerloff (1973), composite samples of the 10 cm terminal segments of healthy *P. crispus* shoots were randomly harvested on June 20 from all study sites (excluding site 5, which had little growth of *P. crispus*). Additionally, a sample of filamentous algae was harvested from site 6. Samples from each site were oven-dried, ground in a Wiley mill, and split samples analyzed by the vanadomolybdate procedure (APHA *Standard Methods* 1981) in our laboratory and by the Wisconsin State Laboratory of Hygiene.

Results and Discussion

Macrophyte Cover

The physical environment in Black Earth Creek is heterogeneous with respect to depth, current, and substrate. These three interrelated factors have a large impact on plant distribution, resulting in highly variable species distribution and abundance. The stream channel widens considerably downstream, increasing from 4.9 m in site 1 to 12.9 m just above Black Earth. The width/depth ratio averages 16.5:1, and also increases in a similar fashion (Table 1). Much of Black Earth Creek is composed of relatively uniform runs broken up by short riffles and pools.

Figure 3 shows the relative distribution of silt, sand, and gravel covering the bottom of the sections surveyed. While the base materials of the stream are gravel and cobbles, silt deposits have altered the character of the substrate throughout the stream, with considerable depths of silt deposited in places (up to 1 m). Sections 3 and 4 were the only ones that had greater than 60% gravel substrate and were similar in width/depth ratios. Downstream sections 5 and 7 had 30% or more sand deposits. Silt deposits were moderately correlated with plant cover ($r = 0.4$, $p \bar{<} 0.001$). Average depths of silt by site are listed in Table 1. Observations indicate that while depths of sediment as great as 80 cm build up in places along the stream edges, much of the areal distribution is made up of shallower (ca. 10 cm) deposits held in place by macrophyte beds. Mace *et al.* (1984) found a 69% (presence/absence) occurrence of macrophytes on silty substrates. Kullberg (1974) also noted the increased frequency of macrophytes on silt substrates. Dense beds of *R. longirostris,* which is usually located on gravel/cobble substrate, commonly trapped 10 cm or more of sediment where the plants were not located directly in a riffle area. Previous observations on Black Earth Creek (Madsen 1982; Madsen and Adams 1985) of *P. crispus* rooting in silt over gravel tend to confirm the impression of its significant local impact on deposition. Macrophytes cause local sedimentation within a plant bed by reducing current velocities (Haslam 1978; Gregg and Rose 1982; Madsen and Warncke 1983). Although moderate siltation may cause a favorable substrate rich in nutrients for macrophyte growth, heavy siltation causes burial and decomposition of macrophyte beds. Therefore, the

Table 1. Averages for environmental factors for study reaches 1 through 7 for June and July.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*all reaches*
% Light	91.8	71.4	29.6	55.6	100	47.1	100	67.1
% Canopy	7.8	33.2	59.2	27.5	0	49.7	0	28.8
Width (m)	4.9	6.1	6.5	8.5	11.2	10.1	12.3	8.1
Depth (cm)	69	45	43	48	38	42	55	49
Width/Depth	7.1	13.6	15.1	17.7	29.5	24.1	22.4	16.5
% Silt	74.7	38.7	15.3	25.9	14	16.2	33.2	32.2
% Sand	5	12.1	5.1	2.2	33.5	27.1	34.8	15.3
% Gravel	20.6	47.6	79.6	71.9	52.5	56.7	32	52.4
Silt Depth (cm)	35	22	10	15	10	16	34	22

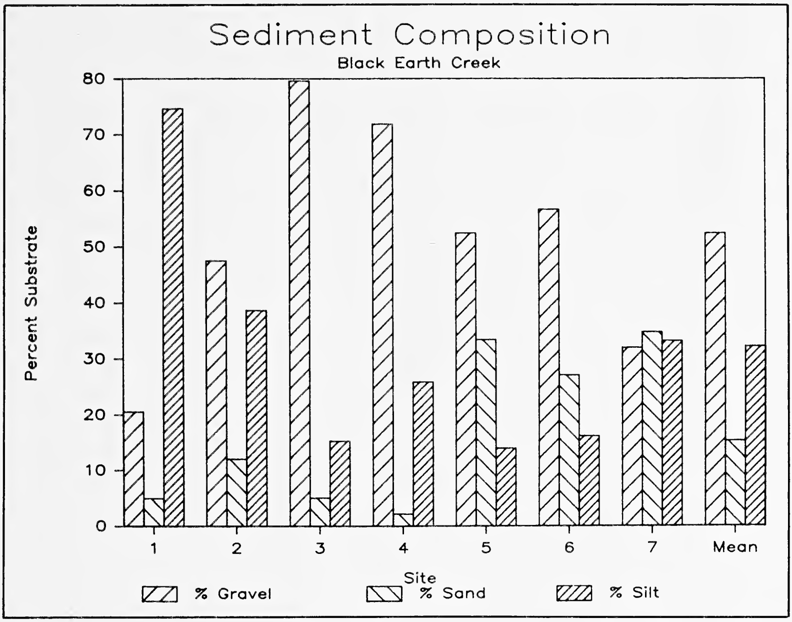

Fig. 3. Substrate composition in percent gravel, sand and silt for study reaches, and mean for all reaches.

higher frequency of macrophytes on silt substrates may be caused by increased siltation in a macrophyte bed, in addition to favorable current velocity or substrate conditions.

The average cover of macrophytes for all seven sites was 55.6% (S.E. = 2.1) for June and July combined. The average for sites 1 through 4 was 60.4%, compared to the 1981 estimates of 68.8% (Fig. 4). Section-to-section variability is high between and within years, especially in section 1. The major change from 1981 is an average decrease in the abundance of the dominant, *Potamogeton crispus.* However, this is most likely due to annual variation rather than directional change in the community.

The community in 1985 was composed of seven species that together made up more than 96% of total cover (Fig. 5). One of the notable differences from 1981 was the scarcity (< 1%) of formerly dominant *N. officinale,* and the relative abundance of *H. boreale,* with 4% cover. In addition, *P. vaginatus* occurred with *P. pectinatus* in similar abundance, especially at site 7. A striking growth of filamentous algae identified as *Rhizoclonium* sp. began in late June and covered large areas of site 5, which previously showed very little vegetation despite its lack of shading. The site is shallow with primarily gravel substrate and scattered *R. longirostris* patches providing anchoring substrate for the usually periphytic filaments. Localized patches of dense filamentous algal growths were also encountered at sites 3, 4, and 6 in shallow areas with exposure to sunlight. Filamentous algae were not quantified in 1981. The increased importance of *Elodea, Potamoge-*

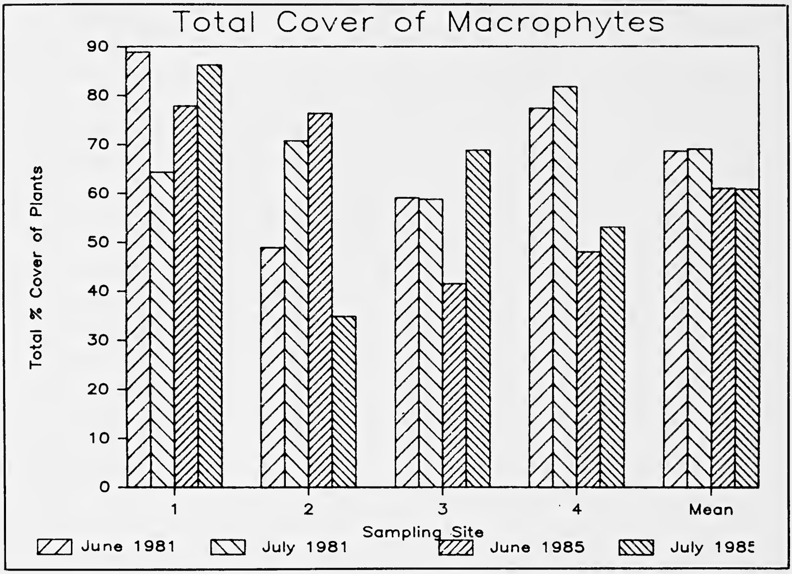

Fig. 4. Percent total community cover in Black Earth Creek for June and July of 1981 and 1985.

ton vaginatus and *Ranunculus* in 1985 versus 1981 is largely due to sampling of the lower reaches (5, 6, and 7) in 1985 that were not sampled in 1981. Similarly, the much higher relative percentage of *P. crispus* in 1981 is in part due to the sampling of only sections 1 through 4. *Potamogeton pectinatus* and *P. vaginatus* are much more prevalent in section 7. A smaller amount of variation in species composition between the two years is due to interannual fluctuations in dominance (Dawson *et al.* 1978).

Overhead canopy was negatively correlated with percent cover of macrophytes ($r = -0.58$, $p < 0.001$) and with the percentage of ambient light reaching the stream surface ($r = -0.87$, $p < 0.001$). This indicates that shading reduces cover and biomass development by significantly reducing in-stream light intensity. The average width of the stream (8–10 m) is narrow enough for effective shade control of aquatic vegetation.

Control of stream macrophytes by shading has been extensively studied and utilized in European streams (Dawson 1978; Dawson and Haslam 1983; Krause 1977; Jorga *et al.* 1982). In Wisconsin, (Madsen 1986) found a 60% reduction in incident light and a 50% reduction in macrophyte biomass in areas of Badfish Creek with natural tree vegetation, as compared to areas with only herbaceous riparian cover. Riparian shading by either naturally propagated or planted tree cover could be a feasible control technique for Black Earth Creek macrophytes. Control of macrophytes should only be implemented if the macrophyte standing crop is considered to be detrimental to the oxygen balance of the stream community.

Over shorter periods of time, light availability in Black Earth Creek may be

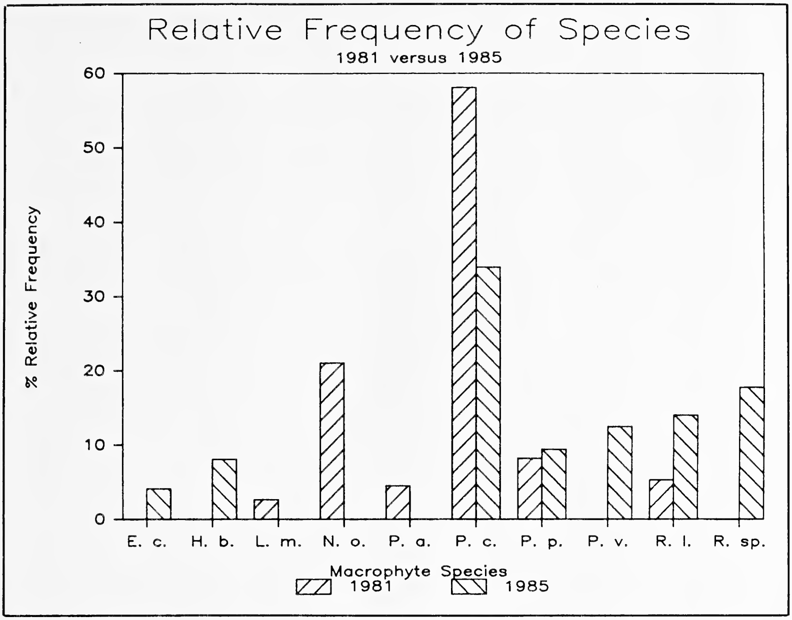

Fig. 5. Relative frequencies of species for 1981 and 1985; E. c., Elodea canadensis; *H. b.,* Hypericum boreale; *L. m.,* Lemna minor; *N. o.,* Nasturtium officinale; *P. a.,* Phalaris arundinacea; *P. c.,* Potamogeton crispus; *P. p.,* Potamogeton pectinatus; *P. v.,* Potamogeton vaginatus; *R. l.,* Ranunculus longirostris; *R. sp.,* Rhizoclonium *sp.*

reduced by water turbidity. Periods of heavy runoff may create turbid conditions for many days, or even weeks (pers. obs.). Variability in turbidity from year to year is one contributor to interannual variability in macrophyte biomass.

Biomass

Biomass provides an estimate of the ability of Black Earth Creek to support macrophyte growth (Table 2). Areas of high biomass and dense growth occurred in and above site 1, indicating that the stream is highly productive well before it encounters the point source of nutrients at Cross Plains. The input of treated sewage effluent from the Cross Plains Sewage Treatment plant does not increase macrophyte biomass, but may stimulate the growth of periphytic algae. Biomass at sites 1 and 7 may be higher than site 3 because of edaphic factors, specifically higher percentage silt. Data from both 1981 and 1985 show site 3 to have lower total cover, due to both different sediment characteristics and higher percent tree canopy.

Biomass sampling was done on Black Earth Creek by Mace *et al.* (1984) in September, 1982 at a location 11 km downstream from Cross Plains yielding an estimate of 282 g m^{-2}. This estimate does not truly reflect potential biomass on Black Earth Creek, since the sample was taken after the senescence of the dominant species *(Potamogeton crispus, P.*

Table 2. Above-ground biomass of macrophytes at three sites in Black Earth Creek (July 1, 1985).

Site	Mean Crop $g\ m^{-2}$	Standard Error	% of species by weight*					
			R	P.c.	P.spp.	H.b.	R.l.	E.c.
1	789.4	92.7	—	45	—	22	10	23
3	334.8	27.0	—	19	—	—	—	81
7	512.1	62.9	4	—	96	—	—	—
MEAN	545.4							

* Species codes: R = *Rhizoclonium* sp. and other filamentous algae; P.c. = *Potamogeton crispus;* P.spp. = *P. pectinatus* and *P. vaginatus;* H.b. = *Hypericum boreale;* R.l. = *Ranunculus longirostris;* E.c. = *Elodea candensis.*

pectinatus and *P. vaginatus).* A maximum biomass range of 500 to 800 g dw m^{-2} is more reasonable and is comparable to values reported for fertile limestone streams in Britain, as well as other streams (Table 3). Mace *et al.* (1984) found an average biomass of 365.5 g dw m^{-2} for Mount Vernon Creek, a nearby stream that receives less point and non-point pollution. Peak values for Badfish Creek, a nearby stream receiving sewage effluent, were 700 g dw m^{-2} in 1983 and 626 g dw m^{-2} in 1984 (Madsen, in prep.). The similarity of values between Black Earth Creek and Badfish Creek support our contention that the macrophytes in these streams are not nutrient limited.

Respiration and Dissolved Oxygen Modeling

Respiration estimates for *P. crispus* and *P. vaginatus* averaged 2.43 and 2.90 mg 0_2 g $AFDW^{-1}$ h^{-1}, respectively (S.E. was 0.59 and 0.14, corrections for AFDW were 0.854 and 0.843). While these are higher than the suggested value of 1.5 mg 0_2 g dw^{-1} h^{-1} as suggested by Westlake (1966), they compare well with values found for similar species by Mace *et al.* (1984) and our unpublished data for *P. pectinatus.* Respiration attributed to microbial and algal activity in the water column was estimated to average 4.3 mg 0_2 1^{-1} d^{-1}, which is approximately 10% of the whole stream respiration estimated below.

The model estimated K_2 (adjusted to 25 C) at 8.52 d^{-1} and Ps and R as 25.1 and 40.7 mg O_2 1^{-1} d^{-1} respectively. The estimated K_2 appears high compared to the estimates of 8.5 to 10 d^{-1} by Grant and Skavroneck (1983) for an area downstream of Cross Plains that has a higher gradient and shallower flow than site 1. However, the K_2 calculated had a rather large confidence interval (5.9–11.1 95% C.I.), and thus the disparity with the expectations based on the results of Grant and Skavroneck is not surprising. Lack of

Table 3. Macrophyte biomass for representative streams and lakes.

Community	Species	$g\ m^{-2}$ Biomass	Reference
Fox Lake, WI	*Potamogeton pectinatus*	293	Kollman & Wali 1976
River Ivel, UK	*Berula—Callitriche*	520	Edwards & Owens 1960
River Test, UK	*Ranunculus pseudofluitans*	385	Owens & Edwards 1962
River Ivel, UK	*Ranunculus pseudofluitans*	320	Owens & Edwards 1962
River Yare, UK	*Potamogeton lucens*	381	Owens & Edwards 1962
River Chess, UK	*Callitriche* sp.	322	Owens & Edwards 1962
Bear River Delta, Man.	*Potamogeton pectinatus*	517	Robel 1961
Lake Suwa, Japan	*Potamogeton crispus*	86.8	Ikusima 1970
Badfish Creek, WI 1983	*Potamogeton pectinatus*	700	Madsen 1986
Badfish Creek, WI 1984	*Potamogeton pectinatus*	626	Madsen 1986

correction in the model for temperature effects may produce an overestimation of K_2. MacDonnell (1982), working on a highly productive hardwater stream in Pennsylvania, noted that K_2 may be overestimated by as much as 27% in such situations.

Effects of dissolved oxygen changes on respiration are probably small, as the observed range was between 6.8 and 13.9 mg 0_2 1^{-1} for the period. This is above the level (5 mg 0_2 1^{-1}) at which large effects on respiration are noted (MacDonnell 1982). Model assumptions about the uniformity of the stream flow can be questioned on the basis of USGS data on groundwater input. Flow may be augmented approximately 40% in the area. While information on the dissolved oxygen content of groundwater is limited, estimates used by a Waste Load Allocation Study in 1977 (WDNR, unpubl.) were approximately 8 mg 0_2 1^{-1}. Input of oxygenated water would tend to reduce calculated rates of respiration with a consequent overestimation of the proportion of macrophyte respiration to total community oxygen usage.

Using the biomass estimate for site 1 of 789.4 g m^{-2} (Table 2) and a conservative estimated respiratory rate of 1.5 mg 0_2 g dw^{-1} h^{-1} (Westlake 1966), macrophyte community respiration would be 28,418 mg 0_2 m^{-2} d^{-1}. Model whole stream R estimated as 40.7 mg 0_2 1^{-1} d^{-1} and an average depth of 0.67 m yields 60,430 mg 0_2 m^{-2} d^{-1}. Thus, a conservative estimate of macrophyte respiration may account for about 47% of the daily ecosystem respiration in the study section. Our respiration estimates for *P. crispus* were somewhat higher than the value suggested by Westlake, so that 68% of community respiration might be due to macrophytes if all species at the site had similar respiration rates to *P. crispus*.

The overall P/R ratio of 0.62 would classify Black Earth Creek as an heterotrophic stream ecosystem, meaning that it is a net consumer of oxygen and theoretically uses more allochthonous than autochthonous energy. This value is within the ranges noted by Hannan and Dorris (1970). While this stream is highly productive on a seasonal basis, the combined respiratory activity of biota require more oxygen from the stream than was produced during this period. While a P/R <1 is surprising in light of the lush growth and healthy condition of the plants at the time of the trials, the model estimates of other small streams commonly produce similar results (M. Tusler, pers. comm.). Small streams are net consumers of dissolved oxygen, and naturally variable faunal production during the season often produces heterotrophy in productive streams (Hynes 1970). A seasonal analysis of P/R may show a great deal of variability in P/R over the year. The P/R ratio may be greater than one during winter, spring and early summer due to low respiratory biomass and low temperatures. As macrophyte (and periphyton) biomass increases, self-shading occurs so that only the upper portion of the macrophyte canopy exhibits net oxygen production, but all of the biomass respires, creating a mid- to late summer depression of the P/R ratio to less than one (Naiman and Sedell 1980). Autumnal P/R will remain below 1 due to decomposition of senescent macrophytes and allochthonous input of deciduous tree leaves. Therefore, a one-time measurement of P/R does not indicate the overall character of a stream as a net producer or consumer of energy and oxygen, but it does indicate whether the stream is a net consumer of oxygen in the summer—the time of critical oxygen levels for sensitive organisms.

Phosphorus Limitation

Table 4 indicates the location of samples and the mean values of tissue P

Table 4. Tissue phosphorus concentrations in Black Earth Creek *Potamogeton crispus* or *Rhizoclonium* sp.

Site/ location	*[P](%)*	*Number of Samples*
1 Mid-site	0.89	2
2 Below Brewery Cr.	0.56	1
2 Above CP STP	0.81	1
3 Below CP STP	0.83	1
3 Downstream end	0.87	1
4 Upstream end	0.75	1
4 Scherbel Rd.	0.73	1
6 Mid-site	1.03	1
6 *Rhizoclonium*	0.53	1
7 Mid-site	0.64	2

found. Samples run by both laboratories yielded results within 5% of each other. Macrophyte tissue P values found were significantly above limiting critical concentrations, indicating that P is not limiting macrophyte growth. Although rooted vascular macrophytes are able to take up P from the water column via the shoots, the bulk of P is usually taken up by the roots from the sediment (Carignan and Kalff 1979, 1980; Carignan 1982; Barko and Smart 1981; Huebert and Gorham 1983).

Tissue P concentrations of filamentous algae were lower than those for *P. crispus,* but were still substantially above critical concentrations exhibited for Cladophoran species. Work done on filamentous algae indicate a range of tissue P critical concentrations for growth from approximately 0.06% *(Cladophora glomerata)* to 0.18% *(Draparnaldia plumosa)* (Gerloff 1975; Gerloff and Krombholz 1966; Neil and Jackson 1982).

While growth-controlling levels and dynamics of P in *Rhizoclonium* are not known, extension of knowledge of *Cladophora* is reasonable. These genera are closely related, possibly even variants of the same genus. Thus, nutritional and other physiological requirements may be quite similar (Linda Graham, pers. comm.). Investigations of Great Lakes *Cladophora* growth would indicate that *Rhizoclonium* in Black Earth Creek is not limited by P concentration in the water column (Canale and Auer 1982; Auer and Canale 1982a,b). Moore (1977) found that filamentous algae in British streams were regulated more by temperature and light than nutrients.

Dense growths and rapid spread of filamentous algae were observed in early July. Temperature conditions and light are probably optimal at this time of year for Cladophoran algae based on responses of related species in the Great Lakes (Graham *et al.* 1982; Lorenz and Herrendorf 1982) and flowing waters (Moore 1977).

Summary

Although percent cover was lower in 1985 than 1981, no significant change in total community cover or composition was detected. *Potamogeton crispus* remained the dominant macrophyte in this community. Filamentous algae were not quantified in the 1981 study, but personal observation indicates that there has been an increase in noticeable filamentous algal colonization.

Tree canopy significantly reduced incident light levels at the stream surface and was thus correlated with decreased macrophyte cover. These data suggest that light is a significant limiting factor to macrophytes in this stream and that shading by streambank trees may be potentially useful in the control of macrophytes.

Biomass in unshaded areas ranged from 335 to 790 g dw m^{-2}, indicating that the Cross Plains Sewage Treatment Plant does not increase macrophyte biomass, as the highest value was found above the treatment plant.

The estimated respiratory contribution to the stream ecosystem of the epiphyte-macrophyte complex was 47 to 68%. This suggests that macrophytes contribute a substantial proportion of the in-stream oxygen demand wherever their growth is dense. If oxygen levels are considered to be seriously depleted in such areas, the control of rooted vegetation by shading may be the only feasible remedial action available. Filamentous algae would also respond to control by shading.

Dramatic growth of filamentous algae in the stream this year prompts questions as to its impact on oxygen levels. Control of algal growth may be amenable to reductions of P from point sources since algae acquire nutrients solely from the water column, but important questions remain to be answered as to the nonpoint levels of P available and whether instream levels could be reduced below limiting concentrations for filamentous algae. Our tissue P data indicate that the algae are not limited by P availability. Phosphorus removal from the sewage treatment plant at Cross Plains is unlikely to have an impact on the growth of either rooted macrophytic vegetation or filamentous algae.

Macrophyte growth in Black Earth Creek is probably controlled by dynamics other than phosphorus limitation. Macrophyte tissue samples analyzed were well above critical concentrations, exhibiting luxury uptake. We reject the notion that macrophyte growth in Black Earth Creek is responding to point source nutrient enrichment, particularly that of phosphorous, because (1) biomass at separate sites bears no relation to point sources of nutrients, (2) plant tissue P concentrations show no evidence of P limitation, and (3) biomass levels found in Black Earth Creek are similar to those found in calcareous streams in other areas of Wisconsin, the United States, and Britain—streams that have a broad range of impacts from human enrichment, from near-pristine to heavily polluted.

The impact of macrophyte-induced sediment deposition in the stream has not been adequately addressed, especially as it affects space and reproduction potential for fish. Optimum values for macrophyte cover have not been estimated in this respect or in regard to spatial requirements of fish or food production.

Aquatic macrophytes provide many benefits to the stream ecosystem, including those used as trout fisheries. However, anthropogenic disturbance of the watershed may cause excessive growths of macrophytes with deleterious effects on natural ecosystems.

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Edgar B. Gordon: Teacher to a Million

Anthony L. Barresi

Each year millions of Americans receive instruction via radio and television. In fact, we take for granted the availability of children's programming such as "Sesame Street," and we expect broadcasters to give us "how to" courses in cooking, home repair, and even remedial mathematics. If questioned we readily acknowledge the importance of media instruction, and yet we give little thought to how such teaching is accomplished. We in this state would be surprised to learn that many of these media instructional approaches were pioneered in Madison by Edgar B. Gordon of the University of Wisconsin. This article will chronicle his professional career and will focus primarily upon the adaption and implementation of the teaching techniques that he developed specifically for radio instruction.

Born in 1875 in Frankfort, Indiana, Gordon received the largest part of his early education in the Winfield, Kansas, public schools. After his graduation from high school in 1893, he moved to Chicago where he studied violin at the Chicago Musical College. In 1900 he became a resident director at the Chicago Commons Settlement House, a satellite of the famous Hull House. Gordon's experiences working with the city's immigrant poor and disenfranchised led him to view music as did the settlement movement's founder, Jane Addams, "as a potent agent for making the universal appeal and inducing men to forget their differences" (Addams 1910). As a result of his choral work in the settlement house, Gordon's interest for teaching music to underprivileged segments of society was whetted. This interest would later influence his innovative activities in community arts and radio instruction.

In 1907, the Gordons moved to Los Angeles to work at the College Settlement, but they soon resolved to return to Chicago. Enroute, the young family stopped to visit family who convinced them to remain in Winfield. Shortly after, Edgar was hired to teach violin and theory for the Winfield College of Music and to organize and conduct a college-community orchestra at Southwestern College (Mullet 1983). Over the next few years Gordon found himself "pretty much in control of the musical resources of the community" (Gordon Papers).

The young music educator achieved some national prominence when, in 1913, Winfield received official state recognition as the Kansas community that could "offer the best environment for raising children." The judges noted that they were impressed with the "unusual manner and degree in which the fine arts were integrated into the life of the community"—a direct reference to those artistic activities influenced by Edgar Gordon (Gordon Papers).

Good Housekeeping Magazine asked Edgar to write an article about the Win-

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field award for the December 1915 issue (Mullet 1983). This article attracted the attention of Peter Dykema of the University of Wisconsin Extension who invited Gordon to deliver a paper on the Winfield activities at the 1916 meeting of the Music Supervisors National Conference. Dykema, a noted figure in American music education, also prevailed upon Edgar to accept a position with the University of Wisconsin Extension faculty as Director of Community Music and Drama (Gordon Papers). In 1921, Gordon became head of the School Music Department in the University's School of Music, a position he held until his retirement in 1944 (University of Wisconsin Employment Records).

Early Radio Efforts

WHA Radio, one of the first radio stations in the nation, resulted from combined efforts of dedicated University of Wisconsin physics researchers and public-spirited programmers. While this station's claim to primacy is disputed, its assertion that it is the oldest American radio station in continual operation is commonly acknowledged. Beginning with the 1915 experimental transmissions via "wireless telegraphy," radio technology grew swiftly through the work of Professor Earl M. Terry and a number of his students. By 1920, WHA was broadcasting daily reports of weather and road conditions as well as farm information (McCarty 1937). That year, Professor Terry, imbued with the Wisconsin Idea concept, engaged Professor W. H. Lighty of the Extension Division to expand service broadcasting activities (Axford 1960). These two men prevailed upon Edgar Gordon in 1921 to present a music program that would eventually evolve into a music appreciation instruction over the radio—likely the first media instruction in the nation and possibly in the world. Using recordings and some guest artists, Gordon instituted

First Music Appreciation Broadcasts (c. 1922).

weekly broadcasts in which he sought to play some "good music and make some explanatory comments that might be helpful in enjoying the music" (Gordon Papers). After the adoption of a more formal instructional format in 1922, Gordon routinely introduced each piece by discussing its composer, the musical form, its historical development and the performing artist(s) (Penn 1940). Within this format he created a Chautauqua lecture hall illusion in the minds of the listeners who, for the most part, were in awe of the medium. The station received letters from listeners living in areas as far away as Montana and Canada. A group of women in Kearney, Nebraska, even used the weekly program as the basis for their music appreciation study (Gordon Papers).

To adapt the lecture hall format to the purely aural radio medium, Gordon developed several unique approaches. First, he exploited the imaginal potential of radio and secondly, he sometimes used on-site participants as "stand ins" for the listening audience. Gordon recounts the employment of both of these techniques during a 1922 Independence Day broadcast. After a patriotic address by a member of the history faculty, Gordon led the radio audience in the singing of America—"a first in the history of radio," he claimed. To encourage the audience to participate, he stimulated their collective imagination by asking them to consider themselves as part of a "great unseen chorus" expressing their patriotic fervor. In order to reinforce this imaginal technique and to provide a vocal model for the listener-singers, he used a small group of studio singers as an on-site chorus. Such commonly employed techniques might appear rather naive to us, but it is highly probable that the July 4th broadcast marked the first time that such approaches were used to encourage active listener participation. Gordon recounted

E. B. Gordon and early studio group (Minnesingers).

E. B. Gordon and Minnesingers visiting children.

that listener response to this broadcast was very enthusiastic. A highly supportive letter from one of the "unseen chorus" is still retained in the State of Wisconsin Archives (Lighty Papers).

Gordon's early efforts in radio instruction were recognized when, in the late 1920s, he was asked to serve as an advisor for the famous Walter Damrosch music appreciation broadcasts for children. As a result of this experience he discovered that active student participation was preferable over passive listening in order that varying attention spans of children and their need for physical involvement while learning be accommodated. Moreover, his experiences as a performer and conductor led him to believe that a child's active interaction and involvement with "good music" was an effective means for developing musical understandings and a lifelong interest in music (Gordon Papers). Gordon's later programming for children reflected this understanding and conviction in the instructional techniques and materials used.

Other Broadcast Experiments

Several radio experiments further honed Gordon's technique for media teaching and advanced the efficacy of radio instruction. In 1929, he and A. F. Wiledan of the University's Rural Sociology Department conducted a radio experiment that for its time was truly unique. Gordon conducted a rehearsal of a 100-voice chorus in Viroqua, Wisconsin from the studio in Madison! Using a twenty-voice choir in the studio, the Professor conducted the rehearsal with them while the Viroqua choir sang along. Because the off-site ensemble could not observe his conducting gestures, Gordon used simultaneous verbal cues to inform them of his musical intent (*Capital Times* press clipping). Later he would often use the verbal cue technique in his programs for children to compensate for the visual limitations of the radio instruction.

In 1930, Gordon, as chairman of the University of Wisconsin Radio Research Committee, devised a project in which his music education students taught music over the radio to twenty-five classes of sixth, seventh, and eighth-grade children. A control group was taught the same material in a standard classroom setting. Comparisons of test results from the radio students and control group convinced Gordon that radio teaching could be a very effective means for music instruction. This project also gave him the opportunity to develop and implement teaching approaches and materials specifically designed for radio teaching (Gordon 1931).

Journeys in Musicland

When WHA station manager Harold B. McCarty conceived the idea for a School of the Air in 1931, he approached Gordon for advice because he remembered the Professor's earlier experimental projects in radio instruction. Gordon expressed the belief that programming for children should be devised that would "assist classroom teachers in the teaching of subject areas for which they were minimally trained." As music was a subject area typically neglected in most rural

E. B. Gordon conducting a radio festival.

schools, McCarty encouraged Gordon to develop a music instruction program (McCarty interview, February 3, 1984). And thus were initiated the "Journeys in Musicland" broadcasts so popular with several generations of children from rural Wisconsin between the years 1931 and 1955.

In these weekly music lessons Professor Gordon taught songs, some basic music theory, and a "considerable amount" of music appreciation. The aim was to "stimulate the interest of children in good music and to cultivate the ability to participate in some form of music activity" (WHA program schedule, September 1933–January 1934). But it took a while before all of these learning activities were included in the programs. For the first few, he confined the activities to listening experiences. Then Gordon began tentative efforts to secure some reaction from the listeners such as responses to rhythm. When his classroom observers reported the apparent success of these action-based approaches, the Professor decided to attempt the teaching of a song. But he was not content that the children should "merely mouth the words"; rather he wanted singing that was tonally pleasing and accurate—difficult goals considering that he could not hear the sung responses to his instructions.

> . . . I finally decided to try. I chose a lovely German folk song which I first asked the children to listen to while it was beautifully sung by a university student. Then I asked the children to hum along while it was sung again. The third time through, the children were instructed to follow along, this time using the syllable "loo," On the fourth singing the words were used (Gordon Papers.

After teaching several songs in this manner Gordon went into the schools to check the results. To his great pleasure, the performance of the children revealed that they were indeed singing with pleasing tone and pitch accuracy.

Two innovative teaching techniques, which might have contributed significantly to this instructional success, are revealed in the Gordon description. First, his selection of a light female voice that closely resembled that of a child provided an aural model for the listeners to emulate. Secondly, while his approach to teaching the rote song was similar to that commonly used during the 1930s, Gordon's adaption for radio was aurally conceived and methodically moved the children from passive to active participation. Simply stated, he encouraged close concentration while listening to the first rendition and gradual performance participation as familiarity with the song was gained. By the "fourth singing," familiarity with the words and music was sufficient and a successful performance was possible (Dvorak interview). Over the course of a year he would teach about twenty songs in this manner and would review them frequently so that they remained fresh in the minds of the children.

The song material taught by Professor Gordon was drawn from two major sources. The largest number of songs were chosen from folk music of Great Britain, America, Scandinavia, Germany, the Slovak nations, Italy, Spain, Mexico, and France—all ethnic groups represented in the population of Wisconsin. The other source of music of "lasting value" was pieces by major composers of symphonic, opera, oratorio, or lieder literature. When adaptions of text were necessary, his wife Edna Gordon acted as lyricist (Gordon song books, 1940–1955).

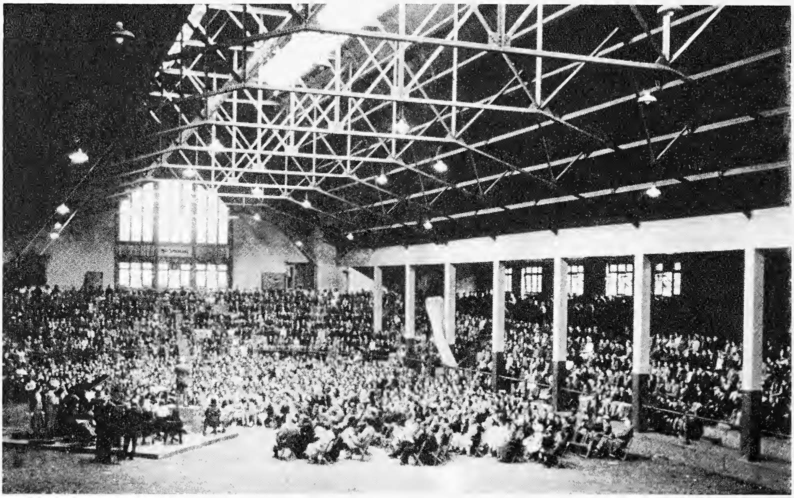
As the years progressed and the educational goals of the "Journeys" program gained more focus, Gordon made a number of changes in the instructional format. In order to create a classroom atmosphere in the studio, he used a group of singers (later named the Minnesingers) who modeled good singing tone for the children and also acted as an on-site class. Evidently, Gordon was drawing upon the "unseen chorus" and "radio choral rehearsal" experiments as sources for this instructional approach. He also developed instruction books that contained all of the songs for the year's programming and music theory information and exercises. These books provided the visual reinforcement that was missing in the purely aural instruction, and they presented additional information that could be studied between programs, should the teacher be so inclined. At first the books were mimeographed, but by 1940, they were published by WHA and sold to the children at cost (Bartell interview). To this day one may still find these song books in the homes of numerous Wisconsin families.

Gordon's previous broadcast experiences had appraised him of the medium's power to stimulate the imagination. He drew upon this potential whenever he created the illusion that the young listeners were part of the class occurring in the studio. Teachers of participating students told the author that the children often felt that the professor was talking directly to them when he admonished "the boy in the red sweater to open his mouth more" or "the girl in the front row to sit up straight when she sings" (Pischke interview). By cultivating a fatherly image that correlated well with his short, rather plump stature, white hair, and kindly sounding voice, Gordon created a radio personality that was loved and respected by the children (Pickart interview).

Gordon further exploited the illusionary powers of the medium and his own charisma by making effective use of the analogy in the teaching of musical concepts and music reading understandings. He often encouraged the performance of crescendo and decrescendo by likening the increase and decrease in dynamics to climbing and descending a mountain. When explaining the relationships of scalar pitches to each other, he would often draw comparisons to relationships common to the experiences of the children. On one occasion he characterized each scale pitch as a neighbor in a child's neighborhood with the first pitch (key pitch or tonic) as home and the eighth pitch (the same tonic pitch one octave higher) as the home of grandparents. He then taught the intervalic relationships of the pitches to the tonic pitch by having the children "visit" (sing) the various neighbors and return home (tonic pitch) from time to time. By effectively employing analogies that stimulated the mind's eye, Gordon was able in another way to compensate for the radio's visual limitation ("Journeys in Musicland" audio tape recording).

Finally, the use of spoken instructions under the singing to give directions or in anticipation of a musical problem was a favorite instructional technique. Ruth Pischke, one of the Professor's studio accompanists, relates that he often gave verbal directions to the children while conducting the studio "class" and that he often joined in the singing to reinforce difficult melodic passages, awkward phrase structures, or tricky rhythms.

While it is difficult to attribute the development of these instructional approaches solely to Gordon, that he adapted them to accomplish his purposes and pioneered in their use is certain. The successes that he achieved by the uses of these instructional approaches within the "Journeys" format are evidenced by the astonishing enrollment figures. In the first year (1931), 793 students participated and in 1955, the last year under Gordon, 70,000 children were registered. Over the twenty-four year period, 1,028,125 Wis-



Radio festival (1940s), 3000 children.

consin children participated in this weekly program (WHA Data Sheet)!

Radio Festivals

The sociological concern that began in the settlement movement of Chicago, and subsequently colored all of his professional career activities, found its ultimate expression in the yearly radio festivals sponsored by WHA. Because the Professor wanted "his children" to experience the "ultimate social experience of music making," he devised the idea of bringing children to Madison for a day to sing together the songs that they had learned in the radio lessons. Such gatherings also gave him the opportunity to better evaluate the effectiveness of his teaching (McCarty interview, June 6, 1986).

From the first festival held in the University's Old Music Hall and attended by 300 children (1934) to those of the 1940s and 50s attended by over 3,000 participants, the response to these gatherings was overwhelming. Increased enrollments over the years caused moves from Old Music Hall to the Stock Pavilion and finally to the largest of the University's facilities, the Field House. When enrollments were so large that the largest auditorium on the campus could no longer accommodate those wishing to attend, the station management and Gordon decided to bring the yearly festival to the children (McCarty interview, Feb 3, 1984). During the mid-1940s the radio professor began to hold festivals in various centers around the state as well as in Madison. By 1956, fifteen festivals were held for about 22,300 children throughout the state (WHA Radio. *The First Fifty Years,* 1969). Recordings of some of these festivals reveal that the children sang with expression, precision, accurate intonation, pleasing vocal quality, and dynamic variation. Obviously, the radio teacher had achieved much more than "just the mouthing of words."

Edgar B. Gordon's radio music teaching represents a unique chapter in Wisconsin's history. Receiving no remuneration for any of his radio work he sought out the musically underprivileged children of rural Wisconsin and administered to their aesthetic needs with the zeal of a social reformer. He was a man who learned from his experiences and one who possessed the creative talent and personal charisma to implement his ideas effectively within the unique educational environment of the Wisconsin Idea. Indeed, the entire state was his classroom.

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Notes from the Notebooks of Cabin #3

"you are incarnate in
the world and we live
caught up in you."

Teilhard de Chardin

"The wicked are like the troubled sea
when it can not rest"

Isaiah 57:20

"one honeymoon day
one honeymoon night
nothing else to say
nothing else to write"

Anonymous

Everyone mentions the "waves," of course,
and the "crying" of the gulls
and the "moon," through the one small window,
"full," "half," or otherwise
provocatively sickled against
a "starry" or "starless" sky,
or as Helen Rusted, of Fond du Lac, put it:

"the thriving mysteries of life
unfolding in waves of time
spiriting through
the vast existence in space."

Many honeymooned or re-honeymooned here,
most are thankful for the change
from whatever to whatever,
everyone goes on almost endlessly
about the peace and quiet.

"we have been married four days
we love each other very much
didn't get seasick listening to the waves

through faith in the lord
we will be married forever."

"do we sound boring,
we don't think we are?"

They had "wieners and cheese for breakfast" or
"crackers and cheese for breakfast lunch and dinner"
or "champagne and meatballs by candlelight"
or "picked blueberries for pancakes
and raspberries in big dishes with cream."

"Had some nice fresh herring."
"hot cookies and milk just out of the cold."

"In this just right cabin,
the carefully watched toast made
on the top of the stove."

The lake was a lullaby, or not.
They loved or hated the bed
which was not "big enough for three"
according to "Don & the girls,"
which was "noisy but
sure held up," "Figgy and Ray,"
in which they slept, if at all,
like a "stone" a "cloud," a lot of "log's"
a "baby" or "the dead."

"We found #3 by pure luck
almost got rammed by a semi."

"The evening of the 19th my wife
got stomach flu
and I got the regular flu
the day after that day."

"fell off the cliff
and lost my shoe but
it could have been worse."

"We came here to be alone
married three years already with a little girl.
This Shawnee's handprint (slightly enlarged)
5 mos. old, 1st time anywhere"

Mrs. Anthony Swanshera of St. Paul
will be back "if I can talk my husband into it,"
and Ginny, Eddie, Lionda, Edvart and Tottsie
are planning to return, in three years,
"God willing."

"We came to find ourselves once more
to remember that what we need
we have already in each other."

"We used to come here as children
now we have children
and grandchildren of our own
and we are still coming"

"We are in or '70's
and it makes a good honeymoon spot"

"We loved each other tenderly
and our fondness increased
as we grew old."

"I sat on the rocks, smoking,
and her reading to me
in the pleasing wild."

"Cassie found the notebooks
and as she read
years and faces came alive."

"It has been good
watching this plan unfold,
creating wholeness
in our life."

Bruce Taylor

note: The quoted material was selected from a series of "guestbooks" dating back to 1937 found in a rental cabin in a small resort on the North Shore of Lake Superior in 1986. People were asked in the original notebook to write whatever they wanted, and provide another when the current one was full.

Diel Patterns of Behavior and Habitat Utilization of Cisco *(Coregonus artedii)* in Two Wisconsin Lakes

Lars G. Rudstam and Todd W. Trapp

Abstract. *Diel patterns of behavior and habitat utilization of cisco* (Coregonus artedii) *differed between lakes and among age groups. At night, cisco were dispersed across both lakes, but three different daytime distributions were observed: cisco were (1) dispersed and distributed across the lake (older fish in Trout Lake), (2) schooled and distributed across the lake (Pallette Lake), and (3) schooled and distributed closer to shore (younger fish in Trout Lake). No diel vertical migration was observed, but the smaller fish in Trout Lake moved toward the shore during dawn and offshore during dusk. Stomach analyses indicate that cisco may feed both day and night. Younger cisco were spatially segregated from older fish in Trout Lake, but there were only small differences in diet between the two groups. Possible causes for differences between lakes and between age groups are discussed.*

Pelagic fishes in lakes often exhibit diel patterns of behavior and habitat utilization. Vertical migrations toward the surface at night are common in planktivorous salmonines (Narver 1970, Eggers 1978) and coregonines (Northcote and Rundberg 1970, Dembinski 1971, Nilsson 1979, Enderlein 1982, Hamrin 1986). However, Engel and Magnuson (1976) did not observe any vertical migration of cisco *(Coregonus artedii)* in Pallette Lake, Wisconsin, during summer stratification. Instead, they reported a horizontal diel migration. The fish moved onshore at dawn and offshore at dusk. Horizontal diel migrations of coregonines have not been reported elsewhere, but such migrations have been observed for percids (Hasler and Bardach 1949, Hasler and Villemonte 1953), cyprinids (Hall et al. 1979, Hanych et al. 1983, Brabrand et al. 1984), and centrarchids (Baumann and Kitchell 1974).

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Engel and Magnuson attributed the lack of vertical migration of cisco in Pallette Lake to the narrow depth interval where temperatures were low and oxygen levels high enough to support cisco (the "cisco layer" of Frey 1955). Vertical migrations would then be expected in larger, deeper lakes with well-oxygenated hypolimnia. In this paper, we present results from an investigation of cisco diel behavior in two northern Wisconsin lakes (Trout and Pallette Lakes) during summer stratification, using sonar and vertical gill nets. We address the following questions: (1) is the horizontal diel migration pattern reported from Pallette Lake consistent over a period of time, (2) can this pattern be found in another lake, and (3) does vertical diel migration occur when the hypolimnion is deep and well oxygenated (Trout Lake, temperatures below 10° C and oxygen levels above 3 mg/l from 12-

m to 30-m depths). In addition, we report data on diel feeding patterns obtained from analyses of stomach content of fish caught during different time periods.

Study Area

Pallette and Trout Lakes are located in Vilas County in Wisconsin's Northern Highland Lake District (46.0°N, 89.7°W). Pallette Lake is a 69 ha seepage lake with a mean depth of 9.7 m and a maximum depth of 19.8 m. It has a low alkalinity (0.15 mmol/l) and can be considered oligotrophic. Trout Lake is a 1605 ha drainage lake separated into four basins. Our investigation was conducted in the largest and deepest of these basins with an area of 770 ha, a mean depth of 18 m, and a maximum depth of 35.7 m. Trout Lake is more productive than Pallette and has an alkalinity of 0.82 mmol/l.

Materials and Methods

Pallette Lake was investigated on 13–15 July 1981 and Trout Lake on 10–12 August, 17–18 August, and 2–3 September 1981. The lakes were surveyed with a 70 kHz echo sounder (Simrad EY-M, 11° beam width) during day, night, dawn and dusk periods. The transducer was towed 0.3–0.5 m below the surface from an "A-frame" in front of a small boat. Towing speed was approximately 1.5–2 m/s. Transects were made along the longest diameter of the lake and perpendicular to this diameter.

Seven 4-m wide multifilament vertical gill nets were used for the catch, each with a different mesh size (19, 32, 38, 51, 64, 89 and 127-mm stretch mesh). The seven nets were set in a straight line for 48 hours from the surface to the bottom along the 14-m depth contour in Pallette Lake (13–15 July) and along the 18-m depth contour in Trout Lake (10–12 Aug.). Trout Lake was fished for an additional 24 hours with 32-mm and 38-mm mesh nets suspended from the surface and with 19, 51, 64, 89 and 127-mm mesh nets suspended from 13-m depth to 28-m depth (17–18 Aug.). The nets were serviced approximately every six hours (Table 1). Fish were identified and their length measured. Depth of catch was noted in 1-m intervals. When available, 10 fish of each 1-cm-length class were weighed in the field using a spring balance. Stomachs

Table 1. Median depth of catch for young-of-year (0+), I+ to II+, and older cisco in Trout Lake. The 25 and 75 percentiles are given in parentheses. Sunrise at 0455, 11 August, and 0503, 17 August. Sunset at 2114, 11 August and 2105, 17 August.

Time period		*Evening*		*Night*		*Morning*		*Day*	
Age group	*Depth sampled (m)*	*median*	*N*	*median*	*N*	*median*	*N*	*median*	*N*
10–12 August:									
Time		1600–2130		2130–0325		0325–1000		1000–1600	
0+	0–18	—	0	14 (14–14)	2	—	0	—	0
I-II+	0–18	15 (15–15)	3	16 (14–17)	12	15 (7–17)	3	—	0
older	0–18	16 (15–16)	3	14 (14–16)	14	15 (12–15)	5	—	0
17–18 August:									
Time		1630–2200		2200–0730				0730–1630	
0+	13–28	17	1	14 (13–18)	12			19 (19–19)	4
I-II+	0–28	18 (12–19)	13	16 (14–19)	33			—	0
older	0–28	26 (22–27)	19	26 (22–27)	26			26 (25–26)	16

from Trout Lake cisco were removed in the field and preserved in 10% buffered formalin.

Settled volume of the stomach content was measured using tapered centrifuge tubes. An index of stomach fullness was obtained by dividing the settled volume by fish weight calculated from a length-weight regression for Trout Lake cisco ($W = 1.3\ 10^{-5}\ L^{2.9}$, weight (W) in g, length (L) in cm, N = 117, range 10–22 cm). This index was not correlated with fish weight ($r = -0.11$, $N = 95$, $P > 0.10$). Prey groups were identified and counted in a subset of the stomachs with a binocular microscope with 6 to 50 times magnification.

Results

Cisco constituted 97% of the total catch in gill nets in Pallette Lake and 87% in Trout Lake. The other species caught, yellow perch, *Perca flavescens,* was always netted above 7-m depth. We therefore considered all targets on echo charts in water deeper than 7 m to be cisco.

All cisco were caught between 7 m and 13 m in Pallette Lake (143 fish) and between 7 m and 28 m in Trout Lake (171 fish). The four cisco caught during the day in Pallette Lake were in the same square meter of netting at 9-m depth. In the deeper part of Trout Lake, cisco larger than 190 mm total length (III+ and older, Rudstam 1984) were caught significantly deeper than younger cisco (Table 1 and 2, Fig. 1).

The sonar charts revealed that cisco were dispersed (not schooled) during the night (indicated by many dispersed echoes in Figs. 2 and 3). At dawn schools were formed both in Pallette Lake and by the shallower, younger fish in Trout Lake. No vertical migration was observed in either lake. The schools broke up at dusk (Figs. 2 and 3). In Pallette Lake, these schools were distributed across the lake whereas in Trout Lake they congregated in areas closer to shore. These diel distribution patterns were consistent among replicate sonar transects (4 day, 4 night, 2 dawn and 2 dusk transects in Pallette Lake; 14 day, 14 night, 4 dusk and 4 dawn transects in Trout Lake). The total absence of smaller cisco in gill nets during the day in Trout Lake (Fig. 1) is also consistent with sonar observations. Older cisco in Trout Lake were caught in deep water both day and night, and sonar charts show dispersed echoes in the deeper water throughout the 24-hour period. No vertical or horizontal migration was observed. The absence of daytime schools of larger cisco could be explained by low light levels (which ranged from 0.1 to 10 mc at 25-m depth in Trout Lake, August 1981, J. Magnuson, unpubl. data). The schools of several fish species disperse at these light levels (see review by Blaxter 1979).

Table 2. Comparison of depth distribution of different size classes of cisco in Trout Lake, Wisconsin. The samples from all time periods are combined for each group of fish.

Comparison 1	*versus 2*	*Depth interval used in analysis (m)*	*Mann-Whitney Z-score*	*P*	N_1	N_2
10–12 August:						
0-II+	older	0–18 m	0.60	N.S.	20	22
17–18 August:						
0+	I-II+	13–28 m	1.08	N.S.	17	41
0+	older	13–28 m	5.10	<.001	17	58
I-II+	older	0–28 m	7.18	<.001	47	61

Stomach-fullness index (settled volume/fish weight) for cisco in Trout Lake did not vary significantly between time periods except for the comparison between morning and night samples from 10–12 August (Table 3). We found what seemed to be newly ingested material in stomachs from fish caught both night and day, and our attempts to classify the degree of digestion in 54 stomachs did not yield significant differences between time periods. Thus, we could not detect any clear diel feeding peaks; cisco in Trout Lake appeared to feed day and night.

The diet was dominated by small zooplankton (copepods and cladocerans) and *Chaoborus* larvae and pupae (Table 4). This is similar to earlier reports (Couey 1935, Engel 1976). Differences were small in diet composition between older cisco caught during day and night as well as between older and younger cisco.

Table 3. Stomach fullness index (stomach fullness/fish weight, in mm^3/g) of cisco caught during different time periods in Trout Lake. Fish over 140 mm total length are included. Only night and morning 10–12 August are significantly different (Mann Whitney Z-score: 2.39, $P < 0.02$).

Stomach Fullness Index			
10–12 August Time period:	Evening	Night	Morning
Median	8.2	3.6	8.4
Range	0.9–9.0	0.9–11.0	2.5–12.4
Fish length (mm)	146–204	148–205	149–207
N	6	21	8
17–18 August Time period:	Evening	Night	Day
Median	10.5	9.1	9.5
Range	1.0–17.6	0.8–22.5	2.4–21.4
Fish length (mm)	144–216	146–226	195–232
N	15	28	17

Discussion

Our observations show that cisco diel patterns of behavior and habitat utilization during summer stratification may differ both between lakes and between age groups and may change with time within a lake. At night, cisco were dispersed across

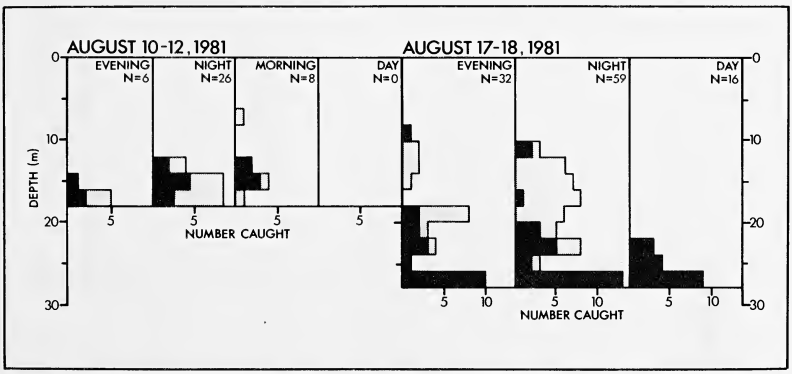

Fig. 1. Depth distribution of cisco I+ and older caught in vertical gill nets in Trout Lake, Wisconsin. The cisco are separated into fish smaller than 189 mm (age I–II+, dotted bars) and fish larger than 190 mm (age III+ and older, solid bars). Except for one fish, all cisco I+ and older were caught in the 32- and 38-mm stretch mesh nets. These nets were set from the surface to bottom (18-m depth, 10–12 August and 28-m depth 17–18 August).

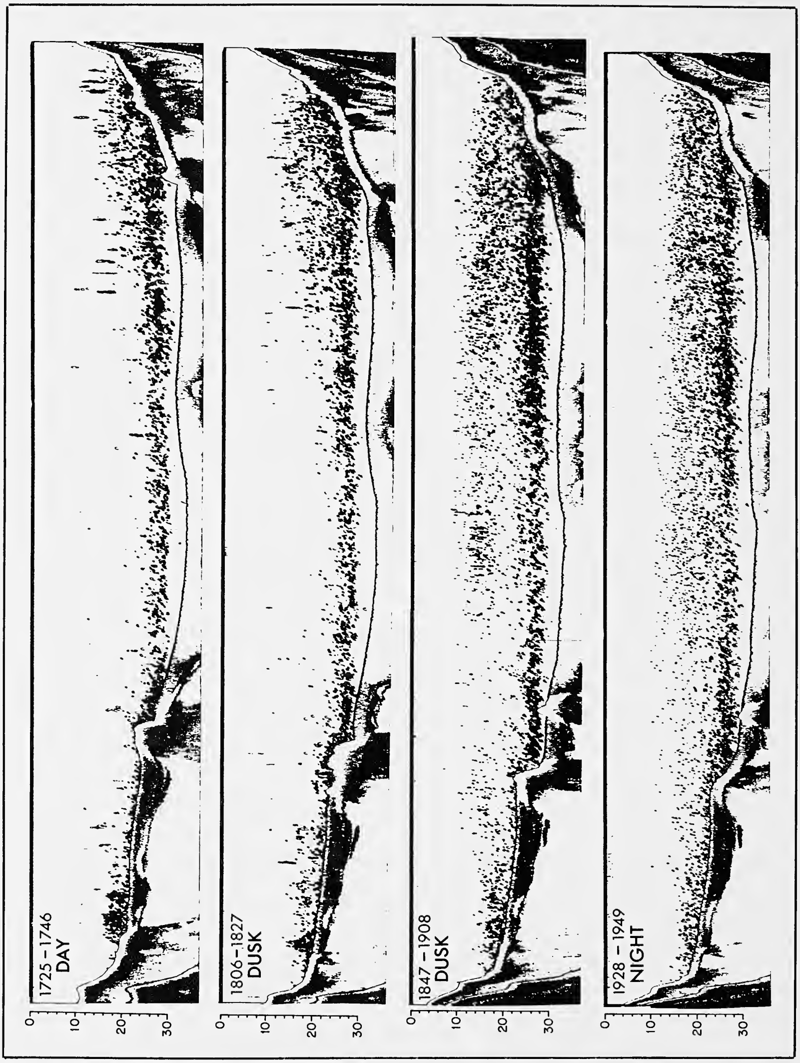

Fig. 2. Sonar charts from 2 September 1981 from the deep basin of the southern part of Trout Lake, Wisconsin. The weather was clear and calm. An eighth moon was up. Sunset was at 1938 CST. Each transect is approximately 2.5 km long.

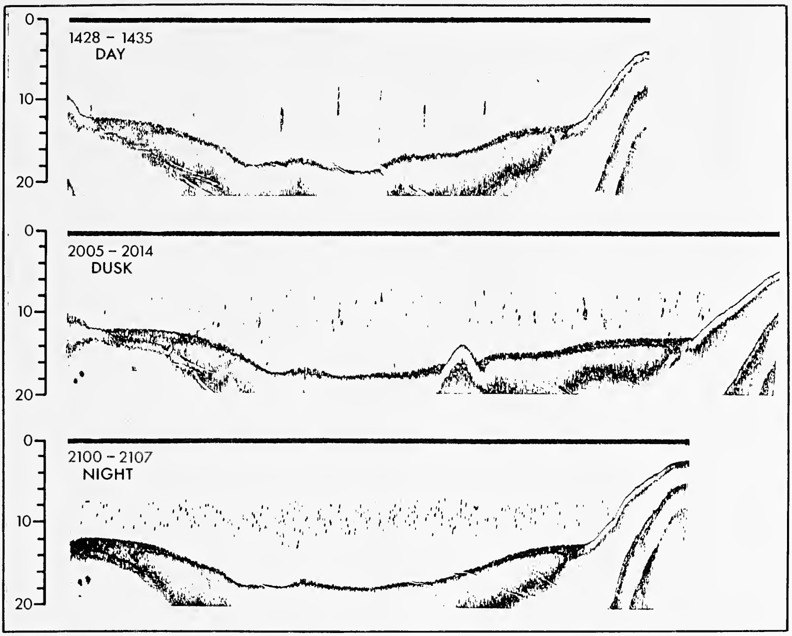

Fig. 3. Sonar charts from 14–15 July 1981 from Pallette Lake, Wisconsin. The weather was overcast and calm with light rain. Sunset was at 1945 CST. Each transect is approximately 500 m long.

both lakes. This can also be observed in other Wisconsin lakes (Big Muskellunge and Sparkling Lake, Vilas Co.; Lake Mendota, Dane Co., Rudstam 1983). However, day distributions differed both between the two lakes and between cisco age groups. Three patterns were observed: (1) fish dispersed and distributed across the lake (older cisco in Trout Lake), (2) fish schooled and distributed across the lake (Pallette Lake), and (3) fish schooled and distributed closer to shore (younger fish in Trout Lake). No diel vertical migration was observed in either lake. Younger cisco in Trout Lake moved toward the shore at dawn and into the middle of the lake at dusk. A similar horizontal migration was observed in Pallette Lake in 1969–70 (Engel and Magnuson 1976) but did not occur in that lake in July 1981.

These observations show that the horizontal migration pattern described by Engel and Magnuson (1976) was not an isolated occurrence. But neither is diel horizontal migration the rule for cisco. Changes in the open water fish community of Pallette Lake between 1969–70 and 1981 indicate the possible importance of inter-specific interactions in regulating diel migration patterns. Large numbers of perch occurred pelagically in Pallette Lake in 1969–70, when cisco migrated horizontally. These perch had an opposite diel movement to cisco, toward the shore at dusk and back to the pelagic zone at

Table 4. Diet of cisco from Trout Lake. Median number of identifiable food items in stomachs for different size classes and time periods are listed. The range, percent by number in the diet, number of stomachs where a food item occurred, and depth of catch are also given.

Date and time period / Age group	Aug. 10–12, Dusk-Dawn, *I–II+*			Aug. 10–12, Dusk-Dawn, *III+ and older*			Aug. 17–18, Dusk-Dawn, *III+ and older*			Aug. 17–18, Day, *III+ and older*		
Food item	median (range)	%[d]	N[e]	median (range)	%	N	median (range)	%	N	median (range)	%	N
Calanoid copepods	2 (0–31)	17	10	2 (0–63)	19	8	230 (0–1604)	42	10	26 (3–570)	21	14
Cyclopoid copepods	12 (2–64)	39	12	6 (0–69)	33	12	216 (32–856)	29	11	40 (4–1840)	40	14
Harpactacoid copepods	0 (0–1)	0.6	3	—	0	0	0 (0–44)	0.4	1	9 (0–604)	12	10
All copepods[a]	30 (3–95)	72	12	7 (0–132)	56	12	556 (212–3047)	89	11	118 (11–2260)	92	14
Daphnia spp.	0 (0–12)	4	5	0 (0–23)	7	3	50 (4–320)	10	11	8 (0–74)	3	11
Other cladocerans[b]	0 (0–2)	0.6	2	0 (0–1)	0.2	1	—	0	0	—	0	0
Ostracods	—	0	0	—	0	0	0 (0–8)	0.01	1	0 (0–2)	0.1	4
Chironomidae[c]	0 (0–2)	1	3	0(0–2)	0.6	4	—	0	0	0 (0–1)	0.01	1
Chaoborus[c]	4 (0–60)	22	10	8 (0–103)	36	11	3 (0–82)	1	10	19 (0–144)	5	12
Fish length (mm)	146–189			191–207			190–216			202–216		
Number of stomachs	12			13			11			14		
Depth of catch (m)	7–18			12–18			22–30			22–29		

a) includes unidentified copepods
b) includes Bosmina spp. and Chydoris spp.
c) includes both larvae and pupae
d) % by number in diet
e) number of stomachs containing the food item

dawn. Engel and Magnuson (1976) suggested that the opposing movements of the two species enhanced spatial niche separation. In July 1981, pelagic perch were rare (only four perch were caught in the gill nets), and cisco did not migrate horizontally.

Vertical diel migrations did not occur even though cisco were not restricted by high temperatures and low oxygen levels to a narrow depth layer in Trout Lake. This differs from observations on vendace (*Coregonus albula,* a related Eurasian cisco), which is generally reported to migrate vertically (Northcote and Rundberg 1970, Dembinski 1971, Nilsson 1979, Enderlein 1982, Hamrin 1986). Vendace feed primarily during daylight hours (Nilsson 1979, Enderlein 1982) and may increase the length of its feeding period by migrating toward the surface at dusk. Since cisco can feed at night (Engel 1976, Janssen 1980), diel vertical migrations may be less advantageous.

Although the diel migration patterns of cisco and vendace differed, both species show intra-specific habitat segregation between age groups (Rudstam and Magnuson 1985, Hamrin 1986). The similarity in diet of different cisco age groups (Table 4) indicates that this segregation was not due to an age-specific preference for different food items that may have been differentially distributed in space. Different size groups of vendace also have similar diets (Hamrin 1983). Hamrin (1986) suggested that younger vendace are more efficient planktivores than larger vendace and that larger fish therefore avoid younger fish to decrease intra-specific food competition.

Engel (1976) reported cisco as feeding during the night, and Emery (1973) classified this species as a nocturnal planktivore. However, neither of these two studies compared fish caught during day and during night. Our somewhat limited data does not support a nocturnal feeding peak. Cisco in Trout Lake appeared to feed both day and night. This is in accordance with laboratory experiments by Janssen (1980) on cisco feeding both in light and in darkness. The fish were size-selective and more efficient in light. However, feeding occurred in darkness even at the lowest prey density tested (16 *Daphnia*/l). The fish were then nonselective. As Janssen points out, the possible effect of cisco predation on zooplankton communities depends on the time of day they feed. This predator-prey interaction is further complicated when diel patterns of habitat utilization exist (e.g. younger cisco in Trout Lake). Cisco may act as daytime size-selective planktivores in part of a lake and as nighttime nonselective planktivores in other areas.

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Nineteenth-Century Temperature Record at Fort Howard, Green Bay, Wisconsin

Joseph M. Moran and E. Lee Somerville

Abstract. *Fort Howard (located near the present site of Green Bay, Wisconsin) was one of several nineteenth-century army posts in the Old Northwest that participated in the nation's first weather observing network. From late 1821 through mid-1841, and from late 1849 to mid-1852, medical personnel at the fort maintained a nearly continuous log of daily weather conditions. A comparison of monthly and annual mean temperatures suggests that recent months and years in Green Bay were generally cooler than the 1820s and 1830s at Fort Howard. However, several factors may affect the validity of this comparison. Specifically, concern surrounds the accuracy, exposure, and location of the Fort Howard thermometer, differences in methods of computation of mean temperatures, and the reliability of Fort Howard's weather observers. Of these, instrument exposure is probably the most troublesome factor for it appears likely that at times Fort Howard's thermometer was exposed to direct sunlight. Such instrument exposure would invalidate comparisons with the modern temperature record.*

Fort Howard, located near the present site of downtown Green Bay, Wisconsin, was a member station of the nation's first weather observing network. In the early to mid-1800s army medical personnel stationed at the fort dutifully maintained a log of daily weather conditions, providing us with a fascinating glimpse of climate for a period when such information was sparse throughout much of the North American interior. Comparison of the Fort Howard temperature record with the modern temperature record at Green Bay suggests that the recent era was somewhat cooler than the earlier era. The principal objective of this study is to assess the validity of that comparison. While there is little reason to question the reliability of Fort Howard's weather observers or the accuracy of the thermometer in use, differences in weather observing practices between then and now pose more serious problems. Of these, differences in instrument exposure appear to be most significant and may well invalidate any comparison between temperatures at Fort Howard and Green Bay.

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The Surgeon General's Weather Network

Because the War of 1812 with the British revealed weaknesses within the medical service of the United States Army, the newly appointed Surgeon General, James Tilton, M.D., set about in 1813 to reorganize the service by drawing up a new set of duties and regulations for all army medical personnel. As part of that reorganization, on 2 May 1814, Tilton issued an order that, in retrospect, marked the first step in the eventual establishment of a national network of weather observing stations (Hagarty 1962). Tilton directed the army medical corp to maintain a diary of weather conditions at army posts with responsibility for weather observations falling to the post's chief medical officer or surgeon. Tilton's objective was to learn more about the climate encountered by troops in the then sparsely populated interior of the continent. He also wanted to assess the relationship between weather and health for it was a popular notion at the time that weather and climate were important factors in the onset of disease.[1]

It took time for Tilton's order to be implemented. The War of 1812 was still raging, and weather instruments had to be acquired and distributed along with directions for proper use. Benjamin Waterhouse, M.D., surgeon at Cambridge, Massachusetts, was the first to submit weather data (for March, 1816). By 1818, reports of weather observations at several army posts began trickling into the Surgeon General's office, and under the direction of Tilton's successor, Joseph Lovell, M.D., the data were compiled, summarized, and eventually published (Lawson 1840). For this reason Lovell rather than Tilton is sometimes credited with being the founder of the government's system of weather observation (Landsberg 1964).

At first, a thermometer and wind vane were the only weather instruments in use at the army posts. The chief medical officer or his assistant read the thermometer daily at 7 A.M., 2 P.M. and 9 P.M. (local sun time), and noted the day's prevailing wind direction and weather conditions. In a column labeled "remarks," comments were entered concerning the health of the troops, phenological events, and any extreme or unusual weather. In 1836, many posts (including Fort Howard) were supplied with rain gages (DeWitt-type) along with very precise instructions on the proper siting and use of the instrument. Rainfall or melted snowfall was measured in inches (to 0.01 in.) at the end of each precipitation. Also beginning in 1836, prevailing wind direction and weather conditions were recorded for both morning and afternoon.

In 1842, the Army Medical Board, in consultation with some of the era's leading scientists, selected and issued new weather instruments along with revised and somewhat more sophisticated observation procedures (Mower 1844). These new procedures were adopted widely in January 1843 (1849 at Fort Howard), and except for observation times the instructions are similar to those issued to today's cooperative weather observers. Temperature, cloud cover (in tenths), and wind direction were recorded four times daily: at sunrise, 9 A.M., 3 P.M., and 9 P.M. The wet bulb thermometer was read at sunrise and 3 P.M., and at some army posts barometer readings also were recorded. Later, in 1855 the Surgeon General's Office shifted observation hours back to 7 A.M./2 P.M./9 P.M., convinced that these observation times gave a better estimate of daily mean temperature.

Medical personnel entered weather data in a journal each day, and quarterly summaries (January-March, April-June, July-September, and October-December) were prepared and then forwarded to the Army Medical Department in Washington, D.C. Tabulations of weather data from all army posts were later published as a series of *Meteorological Registers* (Lawson 1840, 1851, 1855).

By 1838, 16 army posts had compiled at least 10 complete—albeit not always successive—years of weather data. In ensuing years the number of military weather observing stations climbed steadily,

[1] Bates and Fuller (1986) point out that in wartime, even as late as World War I, more soldiers died from non-combat causes (disease, primarily) than from battle.

reaching 60 by 1843, and by the close of the Civil War, weather records had been assembled for varying periods at 143 locations. By the 1870s the Surgeon General's weather network and those operated by the Smithsonian Institution and the U.S. Army Corps of Engineers were merged gradually into a single weather observation network within the Army Signal Corps. Eventually, this new network evolved into the present National Weather Service (Hughes 1980).

Evaluating the Fort Howard Temperature Record

Fort Howard's weather record was among the earliest and most continuous in the Old Northwest (Table 1). The fort was one of several established just after the War of 1812, primarily to assert U.S. authority over the fur trade that had been long controlled by the British (Kellogg 1934). Fort Howard was erected in 1816–1817 on the low, swampy west bank of the Fox River very near the river's mouth at Green Bay (Fig. 1). Earlier the same site was occupied by the French fort, St. François (1717–1760), and the British post, Fort Edward Augustus (1761–1763). Sometime in early 1820, troops were removed from the fort and temporarily garrisoned at Camp Smith, about 6 km up the Fox River. But by late 1821, Fort Howard was again reoccupied. Weather observations began 8 August 1821 and continued until 30 June 1841 when the garrison was withdrawn to Florida for service in the Seminole War and later to Texas to serve in the war with Mexico. With the end of hostilities in 1848, troops returned to Fort Howard, and weather observations resumed for a brief period. Weather records are continuous from 1 October 1849 through 31 May 1852, just prior to final troop withdrawal and abandonment of the fort on 8 June 1852.[2]

The Fort Howard weather record is likely the only weather data available for the early to mid-nineteenth century in the Green Bay area. Between 1852 and the beginning of U.S. Weather Bureau observations in the city on 1 September 1886, only sketchy weather data exist for Green Bay. How reliable then is the Fort Howard weather record, and is it reasonable to

[2] In 1863, the federal government ordered the sale of the Fort Howard military reservation. Although the fort was subsequently razed, several of the buildings remained in use for many decades. Today, visitors to Green Bay's Heritage Hill State Park can view the original Fort Howard hospital (1834–1851) and reconstructed Surgeon's Quarters (1834–1851). The buildings are situated on a hillside overlooking the Fox River about 6 km upriver of the original site of the fort.

Table 1. Location and period of record of weather stations in the Old Northwest operated by the U.S. Army Medical Department

Army Post	*Present Name*	*Period of Record**
Fort Armstrong	Rock Island, Illinois	1824-1835
Fort Atkinson	Fort Atkinson, Iowa	1842-1846
Fort Brady	Sault Ste. Marie, Michigan	1823-1825, 1827-1828, 1830-1842 +
Council Bluffs	Omaha, Nebraska	1820-1825
Fort Crawford	Prairie du Chien, Wisconsin	1822, 1824-1825, 1829-1845
Fort Dearborn	Chicago, Illinois	1832-1836
Fort Howard	Green Bay, Wisconsin	1821-1841, 1849-1852
Fort Mackinac	Mackinac Island, Michigan	1826, 1831-1836, 1842 +
Fort Snelling	St. Paul, Minnesota	1819-1855
Fort Winnebago	Portage, Wisconsin	1829-1845

* Not necessarily complete years of data
Sources: Lawson, 1840, 1851; Miller, 1927

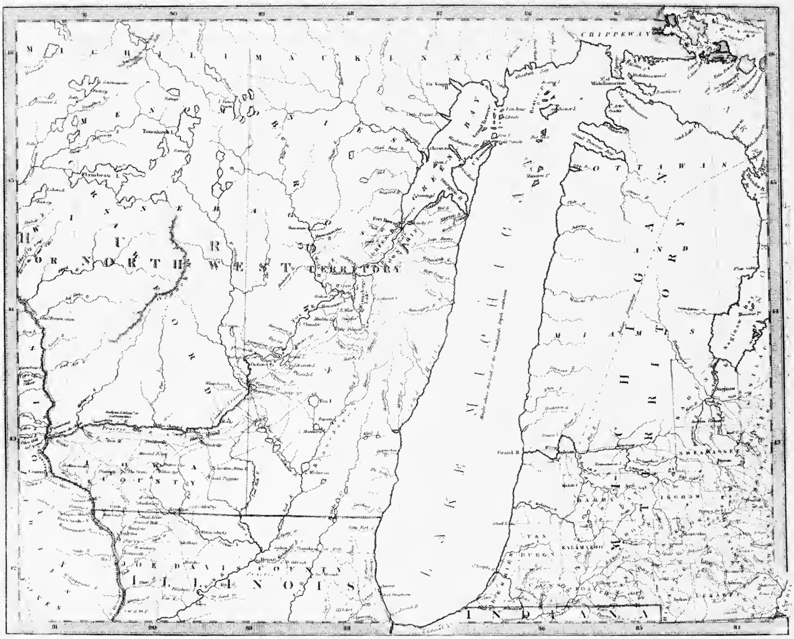

Fig. 1. Fort Howard was located near the mouth of the Fox River at Green Bay. When this map was published in 1833, army medical personnel at the fort had compiled almost 12 years of daily weather data. (North America Sheet V: The Northwest and Michigan Territories, 1833, Society for the Diffusion of Useful Knowledge. From the American Geographical Society Collection, University of Wisconsin-Milwaukee.)

draw comparisons between it and the modern climatic record of Green Bay?

This question is posed because of today's concern over the future course of climate and how variations in climate might affect society, a concern that has sent climatologists in search of an understanding of both how and why climate varies. Perhaps the most direct approach to determining this is to scrutinize closely the record of past climate because, after all, what has happened climatically can happen again. Unfortunately, in most places a reliable instrument-based record of past climate is limited to a little more than 100 years, and such record lengths simply may not encompass the full range of possible climatic variations. The lengthier and more detailed the view of the climatic past, the more data are available to aid in understanding how climate has varied and how it might vary in the future. The potential value, then, of the Fort Howard and other nineteenth-century weather records is evident.

Among the weather elements that constitute the Fort Howard weather record, temperature is the most convenient and perhaps most useful for drawing comparisons between the climate then and now. Except for the 1841–1849 hiatus when the fort was unoccupied, the pub-

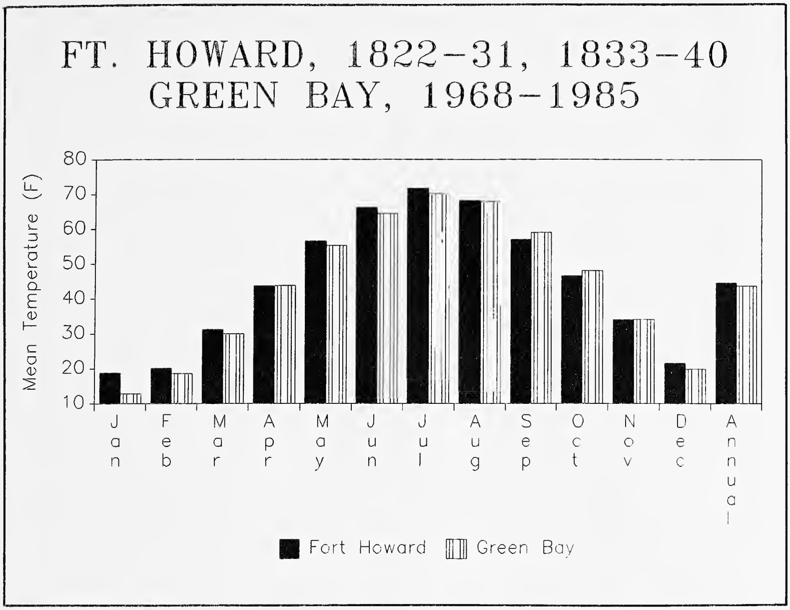

Fig. 2. Comparison of monthly and annual mean temperatures in °F at Fort Howard for 1822–1831 and 1833–1840, and Green Bay, Wisconsin for 1968–1985. Except for April and September through November, the recent period was cooler than the earlier period.

lished Fort Howard temperature record is remarkably complete through the cumulative 22 years and 7 months of weather observations. Only five days within this period (27–31 December 1832) are missing temperature data. Focusing on the first episode of weather observations and eliminating 1832 as well as the incomplete years of 1821 and 1841, there are 18 years (1822–1831 and 1833–1840) for which monthly and annual mean temperature data are available for comparison with the modern National Weather Service temperature record at Green Bay. That comparison is made for a recent 18-year period (1968–1985) in Figure 2 and suggests that, except for autumn (September, October, and November) and April, recent years have been cooler than the 1820s and 1830s. Particularly anomalous is January with a temperature difference of −5.9 F°. But just how realistic is this comparison? Several considerations bear on the integrity of the Fort Howard temperature record and hence, the validity of its comparison to modern climatic data. These considerations are (1) the accuracy, exposure, and location of the thermometer, (2) the method of computation of mean temperatures, and (3) the reliability of the weather observers.

Although we have no direct information on the thermometer at Fort Howard, we do have a description of the thermometer at Fort Snelling, a contemporary of Fort Howard, located near St. Paul, Minnesota. According to Ludlum (1968), William H. Keating, an explorer who visited Fort Snelling in 1823, described the thermometer as "a glass tube attached to a brass plate, on which the graduation was marked" and which was made by "a Mr. Fisher of Philadelphia who sustains a high reputation as a manufacturer of that instrument." D. J. Warner, Curator of the History of Physical Sciences, The National Museum of American History, Smithsonian Institution, advises us (personal communication, 1986) that the Philadelphia city directories from 1793 to 1814 list Martin Fisher (1766–1826) as a thermometer maker. In 1816, he was joined by his son, Joseph Fisher (ca. 1795–1864), who continued the business until 1853. According to Warner, Fisher thermometers were "well regarded" although currently there are none in the museum's collection.

It is reasonable to assume that at least during the 1820s and 1830s, the Army Medical Department supplied all army posts with the same model thermometer, that is, a Fisher thermometer. *If* this assumption is correct and *if* Fisher's reputation as an instrument maker is justified, then we can also assume that Fort Howard's thermometer was accurate. Resting on such indirect evidence, however, this assumption is necessarily tentative.

Since August 1949 official National Weather Service instruments for Green Bay have been located at Austin Straubel Airport. (Previously, they were at downtown sites.) The airport is situated in a rural area of gently rolling terrain about 10 km southwest of the Fort Howard site. All other factors being equal, the airport's

Fig. 3. The waters of Green Bay likely moderated temperatures at Fort Howard on those days when regional winds were light or calm. But the Bay's moderating influence probably had little effect on monthly and annual mean temperatures. (Lithograph courtesy of the State Historical Society of Wisconsin.)

higher elevation (208 meters above mean sea level) versus that of Fort Howard (178 meters above mean sea level) coupled with the airport's greater distance from the moderating influence of the waters of Green Bay would favor a more continental climate at the airport (Fig. 3). (The more continental the climate, the greater is the contrast between summer and winter.) However, based on a comparison of contemporary temperature observations at the airport and at a site near the bay shore (the University of Wisconsin-Green Bay campus), the difference in continentality is insignificant in the time frame of months and years. On days when regional winds are light or calm, winter mornings typically are several degrees colder, and summer afternoons are a few degrees warmer at the airport. Nonetheless, there are only slight differences in monthly and annual mean temperatures.

Since national weather observation practices were standardized in 1873 (year of the founding of the International Meteorological Organization, predecessor of the World Meteorological Organization), monthly mean temperatures have been computed by averaging daily mean temperatures, which in turn are derived by simply taking one-half the sum of the 24-hour maximum temperature and minimum temperature. However, thermometers that register maximum and minimum temperatures and that can be reset once every 24 hours were not in use by the Army Medical Department's weather network (Forry 1842). At army posts, monthly mean temperatures were computed by averaging the mean temperatures obtained for each of the daily observations.

An estimate of the maximum error introduced by differences in the two averaging methods is based on a study by Baker (1975). Analyzing modern climatic data from St. Paul, Minnesota, Baker found that varying the time of day when the maximum/minimum thermometer is read and reset (that is, the observation hour) influences the daily mean temperature and hence, the monthly and annual mean temperatures as well. He noted variations of up to 1.7 F° in annual mean temperature and up to 2.3 F° in monthly mean temperature depending upon the specific hour of observation. Because observation hours at army posts were selected to catch the usual times of the day's lowest temperature (near sunrise) and highest temperature (early afternoon), it appears likely that the actual error arising from the army's averaging method would be less than that reported in Baker's study. Indeed, it is likely that the two averaging methods do not produce statistically significant differences in computations of monthly and annual mean temperatures. This same conclusion was also reached by Wahl (1968) and Thaler (1979) in their respective analyses of the Fort Winnebago (near Portage, Wisconsin) and West Point (New York) nineteenth-century temperature records.

Any question regarding the reliability of Fort Howard's weather observers is probably unwarranted. Although the army's weather observers were not professional meteorologists, the Medical Department supplied them with very detailed instructions on how to take and record weather observations. There were great demands on the time and energy of medical personnel at Fort Howard (and other posts as well) because they were the only physicians within hundreds of kilometers and they tended to the medical needs of the nearby civilian population as well as those of the garrison (Kellogg 1934). It is therefore all the more extraordinary that they carried out their weather observing duties with skill and dedication as is evident from even a cursory examination of the original journals (The National Archives 1952). Of the 10 weather observers who served at Fort Howard between 1822

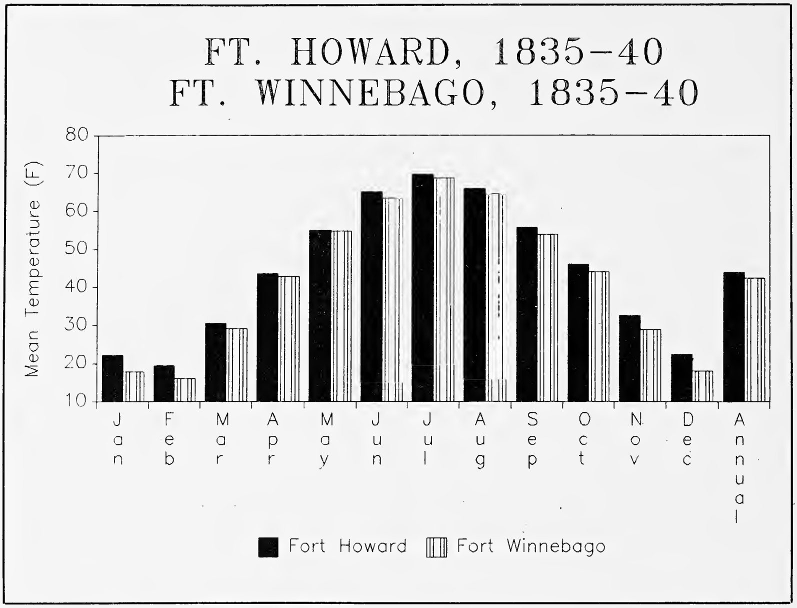

Fig. 4. Comparison of monthly and annual mean temperatures in °F for 1835–1840 at Fort Winnebago and Fort Howard. Even though Fort Winnebago was about 150 km southwest of Fort Howard, this comparison indicates that Fort Howard was warmer than Fort Winnebago—especially in winter.

and 1840, some of course were more diligent than others in their contribution to the "remarks" section of the journal. William Beaumont, M.D. who served from July 1826 to March 1828, was particularly conscientious and often made very detailed notes on weather and health.

Hence, it is reasonable to assume that the Fort Howard weather observers and thermometer were reliable and that the slightly less continentality of the Fort Howard site and the difference in averaging methods would contribute only minor errors to any comparison between Fort Howard and Green Bay temperature records. A much more serious question concerns the exposure of the Fort Howard thermometer.

Instrument Exposure Problem

Today, National Weather Service instruments are housed in a standard white louvered shelter that provides adequate ventilation and protects weather instruments from exposure to precipitation and direct sunlight. Widespread use of instrument shelters dates only to the 1870s even at official meterological stations.[3] Previously, thermometers were usually suspended unprotected just outside a window—and not always a north-facing window. An earlier custom of mounting a

[3] Middleton (1966) reports that in North America the earliest account of a sheltered thermometer was at the Toronto Magnetic and Meteorological Observatory in 1841. The thermometer was in a louvered shelter mounted on the Observatory's north wall.

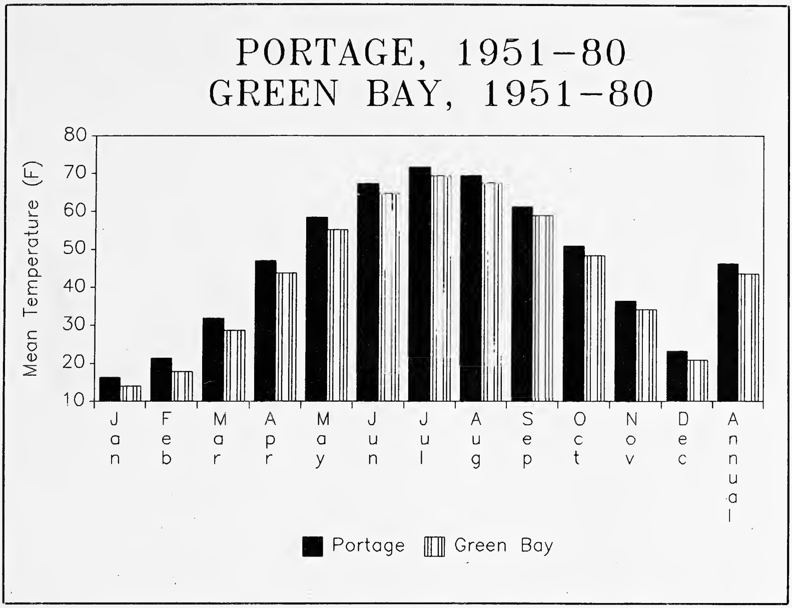

Fig. 5. Comparison of monthly and annual mean temperatures in °F for 1951–1980 at Portage and Green Bay. As expected, Green Bay is a colder locality than Portage.

thermometer indoors in an unheated room had been largely abandoned by the mid-1700s (Middleton 1966). Hence, based on the common practice of the day, chances are that the Fort Howard thermometer was outdoors and unsheltered (Miller 1931).

Studies of nineteenth-century weather records from Fort Winnebago, West Point, and Fort Snelling indicate that at times (diurnally and seasonally) thermometers were exposed to direct sunlight (Wahl 1968; Thaler 1979; Baker *et al.* 1985). This might well have been the case also at Fort Howard. Such exposure would introduce a major systematic error into the temperature record. Further complicating matters, however, is the possibility of undocumented changes in the exposure of the thermometer during the period of record.

Under ideal circumstances there would be other weather records from nearby localities covering the same period that could be used to corroborate the Fort Howard temperature record.[4] Unfortunately, the nearest contemporary army post keeping weather records was Fort Winnebago, located about 150 km to the southwest of Fort Howard. For six complete years of available records (1835–1840) that overlap, Fort Howard was considerably warmer than Fort Winnebago—especially in winter (Fig. 4). However, a

[4] Because variations in climate are geographically nonuniform in both direction and magnitude, the farther apart two weather stations are situated the less meaningful is a comparison of their records.

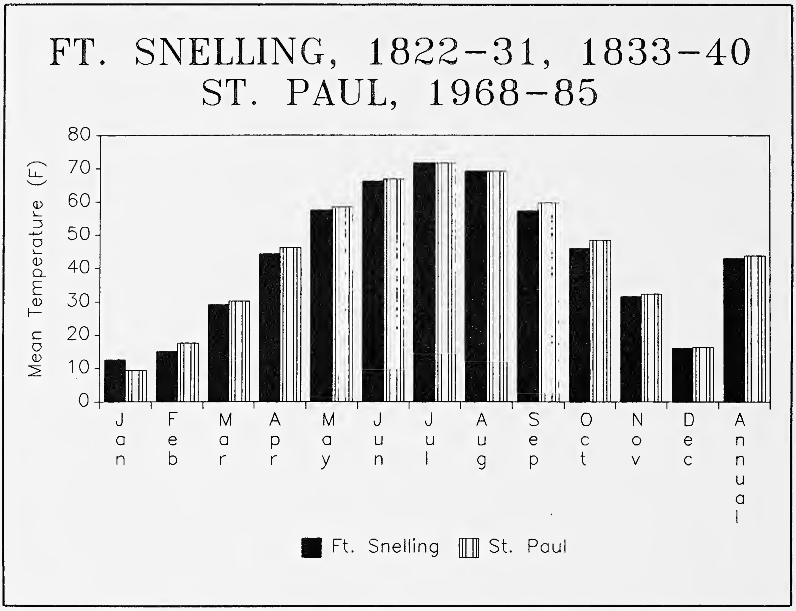

Fig. 6. Comparison of monthly and annual mean temperatures in °F at Fort Snelling for 1822–1831 and 1833–1840, and St. Paul, Minnesota for 1968–1985. Except for January and August, the recent period was warmer than the earlier period.

comparison of modern climatic data from Green Bay and Portage indicates that Fort Howard should have been colder than Fort Winnebago (Fig. 5).

Going even farther afield (about 390 km west of Fort Howard), the Fort Snelling temperature record also suggests that temperature readings at Fort Howard were anomalously high. Baker *et al.* (1985), having the benefit of overlapping temperature records from nearby localities, were able to correct the Fort Snelling record for instrument exposure problems, and they produced a reasonably homogeneous temperature series for St. Paul for 1820–1982. A comparison of monthly and annual mean temperatures at Fort Snelling for 1822–1831 and 1833–1840 with that at St. Paul for 1968–1985 is shown as Figure 6. January is the only month that is cooler in the modern record. A comparison of Figure 6 for St. Paul/Fort Snelling with Figure 2 for Green Bay/Fort Howard supports the conclusion that temperature reports for Fort Howard were too high.

Conclusion

Of the many factors that could impinge on the integrity of the Fort Howard temperature record, improper instrument exposure may be the most significant. In fact, improper instrument exposure may well invalidate any comparison between Fort Howard's temperature record and the modern temperature record at Green Bay. The value of the Fort Howard temperature record then is that it provides insight on nineteenth-century weather observation practices and serves as a warning that early temperature records should be interpreted with caution. On the other hand, the Fort Howard weather logs include data other than temperature that may be useful in comparing the climate of then and now. Specifically, a comparison of the frequency of various weather types (e.g. snowfalls) might be a fruitful investigation.

Acknowledgments

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The Status of Canada Lynx in Wisconsin, 1865–1980

Richard P. Thiel

Abstract. *Eighty lynx* (Felis canadensis) *collected as museum specimens from Minnesota, Michigan, and Wisconsin were associated with periods of lynx invasions from Canada between 1865 and 1980. Historically, the lynx community in Wisconsin probably did not comprise a permanent self-sustaining population but rather was periodically replenished by lynx invasions from Canada. The continued lynx population probably did not persist in Wisconsin much beyond 1900. Factors such as lynx vulnerability, lack of adequate remote habitat, and Lake Superior (which prevents direct lynx movements to and from Canada) inhibit establishment of a Wisconsin lynx population.*

Canada lynx, an intermediate-sized feline, ranges throughout the boreal life zone of North America, and Wisconsin lies on the southern edge of its continental range. Lynx populations are irruptive and closely follow the population cycles of their primary prey, snowshoe hares *(Lepus americanus)* (Keith 1963). Individual survival and lynx population densities increase in response to periods of prey abundance. During and following prey population crashes, lynx densities decrease through emigration and lowered survival rate of individuals. Reliable accounts of lynx in the state are limited to records maintained by fur traders who document that some lynx were encountered in historic times (Jackson 1961). The persistence of reported sightings, tracks (Pils and Swanberg 1963; Pils and Bluett 1984; Schachte 1965; Records-Bureau of Endangered Resources, DNR), and even a few specimens (Doll et al. 1957; Jordahl 1956) have led some observers to conclude that a permanent lynx population currently exists in Wisconsin.

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The present study was undertaken to (1) determine the status of the lynx population in Wisconsin in relation to lynx status and distribution elsewhere in the upper Great Lakes Region and (2) bring together the scattered Wisconsin lynx records so that future researchers may have easier access to the available, albeit meager, data.

Methods

Wisconsin DNR carcass records were reviewed, and in the upper Great Lakes states (UGLS) of Michigan, Minnesota, and Wisconsin, museums were queried to obtain information on the date, location, sex, and method of take for each lynx specimen. Data on date and location of specimens were then compared with documented Canadian lynx irruptions (Elton and Nicholsen 1942; Keith 1963; Gunderson 1978; Mech 1980) to assess whether the occurrence of UGLS lynx specimens were associated with periods of mid-continental invasions. Regional literature, including scientific periodicals, local histories, newspapers, and the annual questionnaires (which solicit observations of lynx in Wisconsin) filled out by bobcat hunters and trappers licensed by the DNR were also reviewed.

While sight and track reports of lynx by citizens are of questionable value, specimens offer bonafide proof of the occurrence of a species. Caution is warranted when utilizing museum specimens in attempting to determine species status because of sporadic or incomplete specimen sampling and because museum collections tend to underemphasize areas where a species commonly occurs. The assumption used to examine the available lynx data is that, in the absence of other explanations, lynx specimens associated with periodic Canadian irruptions indicate the presence of an established population, and conversely, specimen occurrences corresponding with periodic irruptions suggest the absence of a viable Wisconsin lynx population.

Results

UGLS Lynx Collections vs. Canadian irruptions. Figure 1 compares the occurrence of UGLS lynx specimens with peaks in lynx irruptions reported from Canada (Elton and Nicholson 1942; Keith 1963; Gunderson 1978; Mech 1980). In this study eighty lynx specimens—5 from Michigan, 16 from Wisconsin, and 59 from Minnesota, were located in museums. An additional 12 Wisconsin (Table 1) and 3 Michigan non-museum lynx carcass records were included in the analysis. Deposition of lynx specimens into museums has been sporadic; only 28 of the 95 known specimens were deposited in the 85 years prior to 1950.

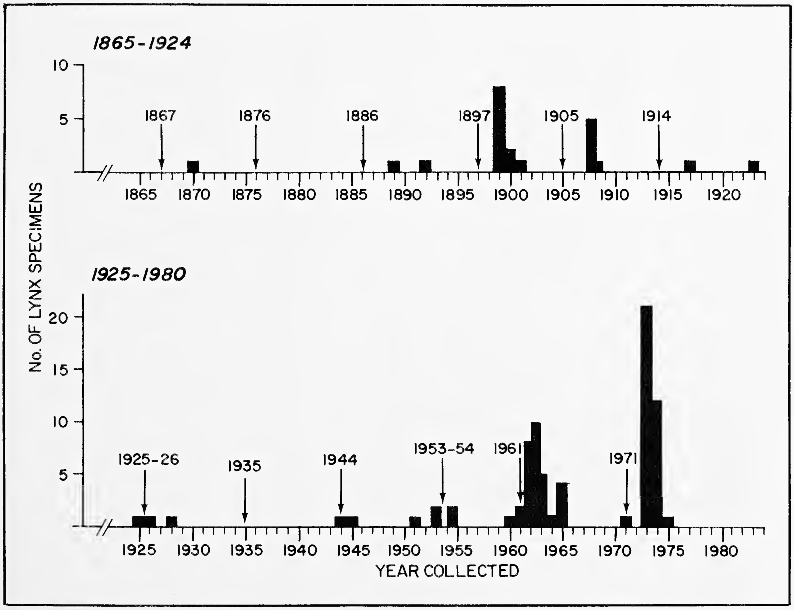

Fig. 1. Relationship between Canadian irruptions (arrows and dates), and the number of Upper Great Lakes states lynx specimens in museums and DNR carcass records.

Table 1. List of 13 non-museum lynx specimens handled by the Wisconsin DNR since 1960 (source, DNR Bureau of Endangered Resources).

Year	Date of Capture	County	Sex	Method of Take	Method of Disposal
1962	Nov.	Rusk	Unk.	Shot	Unk.
1963	Aug.	Douglas	Unk.	Shot	Unk.
1964	Nov. 22	Jackson	Unk.	Unk.	DNR-WI Rapids Office
1965?[1]	Unk.	Pierce	Unk.	Shot	Unk.
1965	Unk.	Green Lake	Unk.	Unk.	DNR McKenzie Env. Center, Poynette
1965	Unk.	Vernon	Unk.	Train-kill[2]	Unk.
1971	May	Trempealeau	F	Shot	Unk.
1972	May	Trempealeau	M	Shot	Unk.
1972	Sept. 17	Oneida	F	Car-kill	DNR Woodruff Office
1972	Oct.	Price	Unk.	Trapped	Unk.
1972	Fall	Lincoln	Unk.	Shot	DNR Rhinelander HQ
1973	Jan.	Iron	Unk.	Trapped	Released
1974	Nov. 20	Marinette	Unk.	Shot	DNR Marinette[3]

[1] Record unclear as to year.

[2] A lynx was killed by a train near Viroqua in 1965; however, another record, based on recollections, lists one "shot" in Vernon County in approximately 1968. The two records probably refer to the same event. The 1965 account appears to be more reliable.

[3] The skeleton of the stuffed skin displayed at DNR Marinette office is housed and catalogued at UW-Marinette Extension campus.

Patterns of lynx irruptions from Canada and the increased collection of UGLS lynx specimens correspond. With the exception of 2 specimens (1889 and 1892), all UGLS lynx specimens have been associated with Canadian irruptions. The mean lapse between Canadian irruptions was 9.5 years while the mean lapse between collection of Wisconsin lynx specimens was 9.7 years. Collection of UGLS lynx specimens lagged 0 to 3 years (1.5 average) behind Canadian irruption peaks.

Lynx Behavior. Fearless behavior toward humans is sometimes displayed by lynx during invasions (Adams 1963; Mech 1973; Gunderson 1978). This behavior has also been observed in Wisconsin and promotes the association of lynx presence in the state with periods of invasions. In July 1926, a lynx was shot while sitting on the top of a street lamp in downtown Shell Lake (Washburn Co.) (Stouffer 1961), and in the fall of 1972, one was shot after reportedly attacking a man who was working in his garden within the City of Tomahawk (Lincoln Co.) (A. Loomans pers. comm.). The relative "boldness" of lynx during population irruptions increases their vulnerability.

Recent Lynx Observations in Wisconsin. Since 1976 Wisconsin DNR annual bobcat hunter/trapper questionnaires have solicited observations on lynx. A mean of 7% of respondents reported observing lynx tracks between 1976 and 1984 (W. Creed and C. Pils pers. comm.), ranging from 2% (1984) to 14% (1976). Wisconsin's northwestern counties have the highest percent of lynx observations (Fig. 2) with Douglas County, which lies adjacent to Minnesota, having the greatest number of lynx observations. This observation pattern is expected when lynx movement from Canada occurs.

Sex Ratios. The sex ratio of 11 Wiscon-

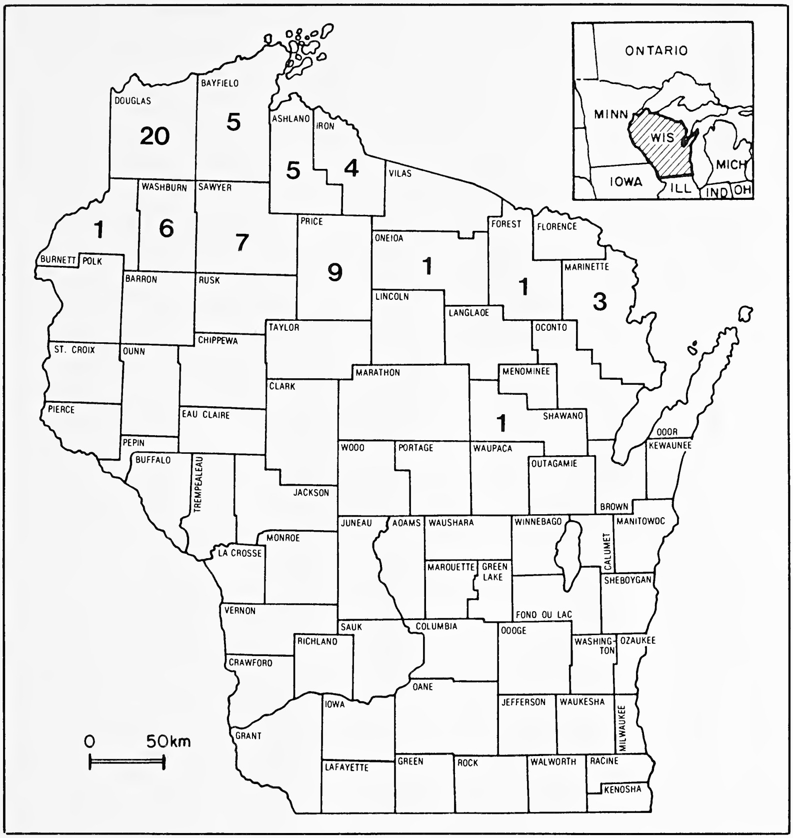

Fig. 2. Number of lynx reports, by county, obtained from annual DNR bobcat harvest questionnaires, 1976–1984.

sin lynx for which sex was recorded was 3 males and 8 females. Of these, the sex ratio of 3 lynx taken in the southern half of the state was 2:1 while the ratio of 8 taken in the northern portion was 1:7. Mech (1980) observed an even sex ratio among lynx during the 1972–73 peak in lynx numbers in northeastern Minnesota and a prevalence of female lynx as numbers declined in subsequent years. The same phenomena was noted in Manitoba during the 1971–73 irruption period (Koonz 1976).

Cause of Mortality and susceptibility. Of 18 Wisconsin lynx for which cause of death was known 13 were shot, 3 were trapped, 1 was struck by a vehicle, and 1 was struck by a train. Large numbers of lynx were trapped or shot in North Dakota following the 1961 irruption (Adams 1963), and Henderson (1978) and Mech (1980) noted that lynx were shot, trapped, and hit by cars in Minnesota during 1971–75.

Discussion

Lynx Population in Wisconsin

Comparisons of dates of known lynx mortalities in the UGLS (Fig. 1) and in Wisconsin (Table 1) with Canadian irruption patterns (Fig. 1) indicate that lynx in Wisconsin and the UGLS are associated with periodic invasions of lynx from Canada. The behavior of lynx within Wisconsin and elsewhere in the UGLS suggests an origin from areas of Canada where there is little or no contact with humans.

Lag time variations occur in Wisconsin and elsewhere south of Canada and are a function of distances from population centers, the amplitude of the irruption period, as well as the relative size of the Canadian population of lynx during irruptions. Peak numbers of lynx in Minnesota and North Dakota occurred in 1962–63 while peaks in Montana (Gunderson 1978) and Wisconsin occurred in 1963–64 (this study) following the massive 1961 Canadian irruption. The effect of distance on lag time was illustrated by comparing the season where lynx carcass retrievals peaked in the northern and southern portions of Wisconsin. Peak lynx occurrences in southern Wisconsin (spring) lagged one full season behind peak northern occurrences (winter). Four lynx recovered in southern Wisconsin (Jefferson Co. 1870; La Crosse Co. 1917; Green Lake Co. 1965; Vernon Co. 1965) lagged three to four years behind the Canadian irruptions.

Lynx that may be present in Wisconsin between irruptive peaks probably represent individuals that failed to return to Canada following periodic population surges. If a viable lynx population existed in Wisconsin, greater numbers of lynx would be taken incidental to other hunting and trapping efforts, at least during irruptions, and some lynx would be expected to be taken between years of irruptive peaks (Bailey et al. 1986; Koonz 1976; Mech 1980). This is not indicated by either the museum specimens or DNR (carcass) records.

A continuous lynx population probably has not existed in Wisconsin since about 1900. Historical records (Jackson 1961) suggest that lynx populations in Wisconsin probably fluctuated dramatically and thus probably have been dependent upon periodic influxes from Canadian population centers for rejuvenation. The importance of these periodic irruptions to lynx viability in Wisconsin was probably similar to the ebbing and waning of turkey (Schorger 1942) and quail (Errington 1967) population distribution in Wisconsin during pre-settlement times. Lynx populations may never have been totally self-supportive since Wisconsin lies at the southern edge of the species' continental range.

Prospects of Lynx Recovery Within Wisconsin. Lynx are not a viable species within Wisconsin. No documentation of breeding has been found historically or within recent times in the state. Individual lynx are periodically present in Wisconsin, however, especially following Canadian irruptions. Conceivably the establishment of a resident lynx population within Wisconsin could occur if some individuals successfully colonized areas of the state following an invasion period. Since 1900, however, there have been eight Canadian irruptions of various magnitudes (Fig. 1), but lynx have failed to become established in Wisconsin. Apparently, insufficient numbers of lynx enter the state to establish a viable population or conditions in the state are not conducive to maintaining a permanent, resident population.

Lake Superior serves as a barrier against southward movements of lynx into Wisconsin and upper peninsula Michigan. Gunderson (1978) noted that lynx occurrences in Wisconsin and Michigan were substantially fewer than from Minnesota and North Dakota during the 1961 irruption and suggested that the Great Lakes "impeded the southward movement" of lynx. Likewise Mech (1973) and Henderson (1978) noted unusual numbers of lynx west from the tip of Lake Superior as they moved south out of Canada.

The possibility of establishing a lynx population in Wisconsin might be enhanced through proliferation of a Minnesota lynx population that is speculated to exist (Henderson 1978; Mech pers. comm.; Boggess pers. comm.). About 650 lynx were harvested in Minnesota between 1972 and 1974. By 1975, however, none were harvested (Mech 1980). Lynx were classified as a "protected" species in Minnesota in 1976 with a limited season established by the state. Annual seasons, not exceeding two months, were held from 1976 through 1983, and the season was closed entirely in 1984 and 1985. It is uncertain whether a resident lynx population will expand in Minnesota under current management strategies.

Mech (1980) postulated that the rapid disappearance of lynx from northern Minnesota in 1974–75 was due to human-caused mortality and possibly the return of lynx to Canada. Mech (1977) documented the latter phenomenon with a female captured in Minnesota in 1974 that was trapped 480 km north in Ontario in 1977. Although return movements of lynx may diminish the chances of establishing a population in Wisconsin, it is also probable that Lake Superior acts as a barrier to northward movements of lynx once they reach Wisconsin. This may explain the presence of a few lynx records from southern Wisconsin up to four years after Canadian irruptions.

Large numbers of lynx are killed incidental to other types of hunting and trapping in the UGLS following invasions. Lynx may be overexploited in and around regions accessible to humans (Bailey, et al. 1986), and they appear to be more susceptible to hunting and trapping than wolves *(Canis lupus)*. Accessibility facilitates increases in human activity, which is known to limit wolf survival (Thiel 1985). Lynx are not prevalent in northern Minnesota where the largest viable wolf population in the conterminous U.S. exists. It seems that human activity has more of an impact on lynx than on wolves. Given present conditions it is doubtful that lynx could become established in Wisconsin, where wolves are highly endangered, partly because of the greater access and higher levels of human activity.

Recommendations

Lynx should remain listed as an endangered species in Wisconsin, and wildlife officials should be alert for signs of lynx proliferation following Canadian irruptions. It is recommended that the DNR (1) adopt a policy to collect information on the date, location, age, sex, reproductive status, and method of kill for all future lynx carcasses recovered in Wisconsin, (2) require that all future lynx carcasses be deposited in recognized museum collections where retention of pertinent data is assured, and (3) incorporate lynx identification and education efforts as a part of its youth hunting and trapping programs.

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The author wishes to thank the staffs of the following for their cooperation: University of Wisconsin (UW)-Madison Zoology Museum; UW-Stevens Point Museum of Natural History; Milwaukee Public Museum; National Museum of Natural History; University of Michigan Museum of Zoology; James Ford Bell Museum of Natural History; Field

Museum of Natural History; Science Museum of Minnesota; Biology Departments of UW-Superior and UW-Marinette; Lake Superior State College; and Northern Michigan University. Thanks are extended to numerous reviewers for their suggested improvement of an earlier draft of this paper. This paper is supported by Wisconsin citizens who have contributed to the Endangered Resources tax checkoff program.

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The Flora of Wisconsin Preliminary Report No. 69 Euphorbiaceae—The Spurge Family

James W. Richardson, Derek Burch, and Theodore S. Cochrane

From the diminutive seaside spurge of the Great Lakes strand to the gorgeous Christmas poinsettia of Mexico and the giant rubber trees (genus *Hevea*) of Amazonia, the Euphorbiaceae is one of the largest families of flowering plants. Its 300 genera and at least 7,000 species are ecologically diverse and widely distributed, especially in the drier tropics. Most are said to be poisonous, a few are troublesome weeds, and a wide variety are cultivated as ornamentals *(Acalypha, Euphorbia, Poinsettia, Ricinus, Codiaeum).* A few others are valued for their economically important products, including food *(Manihot utilissima),* natural rubber (*Hevea, Manihot* spp.), oils *(Ricinus, Croton, Aleurites),* dyes *(Sapium, Mallotus),* and drugs *(Jatropha curcas, Croton tiglium).*

The Euphorbiaceae are clearly a specialized family, as shown by the advanced morphology of its greatly reduced flowers, especially the peculiar flower-like inflorescence (cyathium) of *Euphorbia* [sens. lat.], and the complex secretory tissues, which besides latex (often white) produce a great variety of compounds. Of its two major floral patterns, the "Euphorbia-type" is exhibited by the tribe Euphorbieae and the genus *Dalechampia,* and the "non-Euphorbia-type" by the remaining genera. In the latter, the perianth is 5-merous, except where one or both of the whorls are absent, and the staminate flower generally has 5 or 10 (or up to 400 or more) free or variously united stamens. A lobed disk is commonly present, at least in the pistillate flowers.

The basic unit of the "Euphorbia-type" inflorescence is a complex, highly specialized cymose inflorescence called the *cyathium* (Fig. 1), containing a solitary pistillate flower surrounded by few to several groups (cymules) of staminate flowers. The pistillate flower consists of only a single naked pedicellate pistil, each staminate flower of only a single stamen jointed to the pedicel (Fig. 1). Each small aggregation of these tiny naked flowers is surrounded by a hypanthium-like involucre, the individual bracts of which are discernible as lobes at the rim. The cup-shaped or urn-shaped involucre usually bears 1 to 5 (or more) glands on the top between the lobes and sometimes also horn-like or petaloid appendages. That the cyathium as a whole simulates a single bisexual flower (pseudanthium) is enhanced by the central stipitate ovary (Fig. 1). In fact, the compound inflorescence of irregularly clustered cyathia at the summit of the stem may itself mimic a giant flower, as in *Poinsettia.*

The fruit is customarily referred to as a capsule, although strictly speaking it is a capsular schizocarp. When ripe, the dorsal walls of the locules separate septicidally from the persistent central axis (colu-

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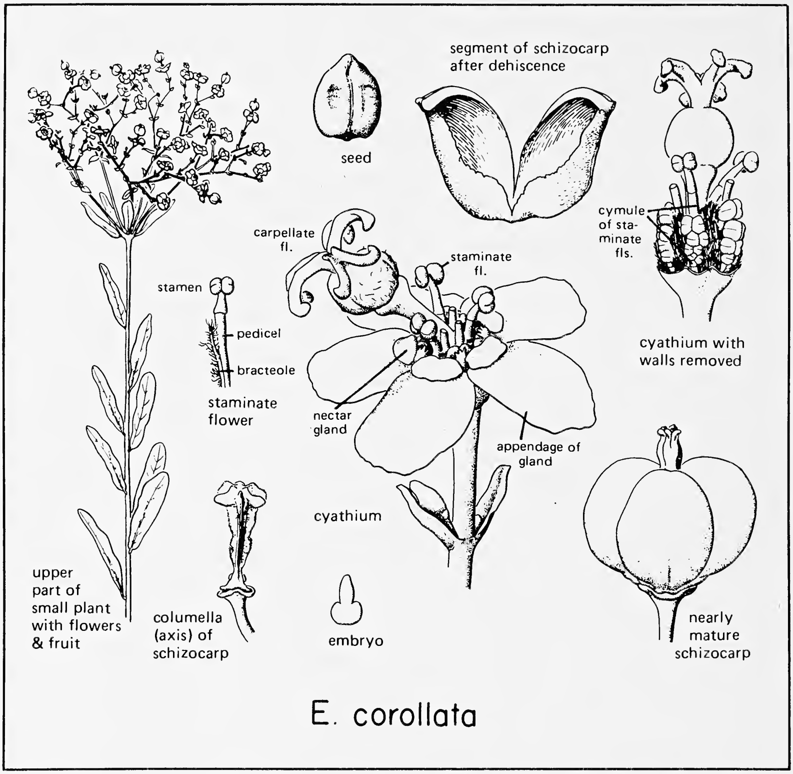


Fig. 1. Euphorbia corollata. *Habit of plant and parts of the cyathium during staminate and fruiting stages. The "Euphorbia-type" inflorescence or cyathium consists of many reduced staminate flowers and a solitary pistillate flower surrounded by a hypanthium-like involucre. (From Wood, 1974.)*

mella) into 1-seeded mericarps, which eventually liberate their seeds through a ventral opening of the locules.

During development and maturation a cyathium passes through five basic stages, which are apparently quite similar among different species. These stages have been described and illustrated by Ehrenfeld (1976).

The Linnaean *Euphorbia* is probably one of the most broadly inclusive genera that still has wide currency in the modern literature. The problem of whether to treat the genus in its entirety or to split it into several genera is one that will undoubtedly be discussed for years to come. In the major early surveys (Boissier 1862; Pax & Hoffmann 1931) *Euphorbia* was retained intact. Subsequent workers have attacked the problem in several ways, either 1) combining all proposed generic segregates into the single large genus *Euphorbia* (Gleason & Cronquist 1963; Voss 1985); 2) reducing such segregates to sections or subgenera of *Euphorbia* (Norton 1900; Wheeler 1941; Fernald 1950; Gleason 1952; Richardson 1968; Walters & Tutin 1968); or 3) recognizing these as separate genera (Rydberg 1932; Small 1933; Croizat 1936; Dressler 1961; Burch 1966b). In the present treatment we follow the latter authors and regard certain natural, albeit weakly defined, segregates as worthy of generic rank.

A recent paper by Webster (1967) is perhaps the best single reference to consult for a more detailed account of the systematics and phylogeny of the Euphorbiaceae.

The present paper revises Fassett's (1933) treatment of the Wisconsin Euphorbiaceae. It is based on specimens deposited in the herbaria of the University of Wisconsin System, namely Madison (WIS), Milwaukee (UWM), Oshkosh (OSH), La Crosse (UWL), River Falls (RIVE), Rock County Center-Janesville (UWJ), Green Bay (UWGB), Platteville, and Eau Claire, as well as Milwaukee Public Museum (MIL), University of Minnesota (MIN), University of Iowa (IA), and the private herbarium of Katherine D. Rill (Oshkosh, Wisconsin). Thanks are due to the curators of the above herbaria for loans of specimens.

Dots on the maps represent specific locations where specimens have been collected; triangles indicate county records when specific locations are not known. The numbers within each map inset in the lower left-hand corner show the amount of flowering and fruiting noted on all the specimens observed and indicate the months when the species may be expected to flower or fruit in Wisconsin. Specimens with vegetative growth only or buds or dispersed fruits are not included. For introduced species and obvious adventives the year of earliest collection within a county is also recorded.

EUPHORBIACEAE[1] Juss. Spurge Family

Monoecious or rarely dioecious herbs, annual (but occasionally perennating) or perennial, some with milky latex in all parts. Leaves simple, alternate or sometimes opposite, usually with stipules. Inflorescences spicate, unisexual or bisexual, or with very reduced flowers collected inside a small cupulate perianth-like involucre to form a pseudanthium (cyathium). Flowers always unisexual, much reduced, the calyx or corolla minute or either or both lacking. Staminate flowers usually several, with 1-many stamens. Pistillate flower solitary; ovary superior, 3 (rarely 1-2)-locular, each locule with a separate style and 1 ovule. Fruit a capsule, typically dehiscing elastically into 3 (very rarely 2) 1-seeded segments (mericarps). Seeds often caruncúlate.

Perennial species flower in late spring or summer. Most of the annuals become fertile while very young and have all stages of flower and fruit present after a few weeks of growth.

A vast and diverse, mostly tropical family, represented in Wisconsin by a miscellaneous assemblage of 22 species in 5 genera (only 3 if *Euphorbia* is viewed as an all-inclusive genus). Many of the species are decidedly weedy and are common in disturbed habitats. *Phyllanthus tenellus* Roxb., an Old World species adventive in the southeastern U.S., was collected "among cult. garden flrs." at Madison in 1983 (*Bremer 21,* WIS). It is a glabrous annual that lacks latex and has tiny pendulous flowers solitary in the axils of alternate entire leaves. It is not, as yet, an element in our flora.

[1] Descriptions and keys apply to Wisconsin material only.

KEY TO GENERA

A. Flowers clearly unisexual, variously arranged but not collected into cyathia; staminate or pistillate flowers or both with a perianth; juice watery.
  B. Plants pubescent with at least some stellate trichomes; staminate flowers mostly with biseriate perianth; pistillate flowers without a leafy bract (Subfam. CROTONOIDEAE Pax). . . . . 1. *CROTON.*
  BB. Plants sparsely pubescent with simple hairs; staminate flowers apetalous; pistillate flowers encircled by a prominent leafy bract (Subfam. ACALYPHOIDEAE Ascherson). . . . . 2. *ACALYPHA.*
AA. Flowers (one central pistillate and few to many staminate) aggregated within a cupulate involucre (cyathium) simulating a single flower; flowers without a perianth; juice milky (Subfam. EUPHORBIOIDEAE).
  C. Glands of cyathium 1 (rarely 2 or 3), without appendages; leaf bases essentially symmetrical; cyathia irregularly clustered at summit of erect stem and ascending branches; annuals. . . . . 3. *POINSETTIA.*
  CC. Glands of cyathium consistently 4 or 5, exappendiculate or with petaloid or horn-like appendages; leaf bases and cyathia various; annuals or perennials.
    D. Leaves all opposite, with distinctly inequilateral bases; cyathia solitary in upper axils or in axillary glomerules (not in "umbels"); annuals with stems low, prostrate or ascending (rarely suberect or tips erect); stipules well developed. . . . . 4. *CHAMAESYCE.*
    DD. Leaves alternate at least below, with ± equilateral bases; cyathia in a terminal umbelliform cyme; annuals or perennials with stems tall and erect (rarely ascending); stipules none . . . . 5. *EUPHORBIA.*

1. **CROTON** L. Croton

Monoecious annual (ours) *herbs* without milky latex, variously pubescent with at least some stellate trichomes. *Leaves* alternate (appearing opposite just below the inflorescence), stipulate, with an unlobed blade. *Inflorescences* dichasial or subcapitate, terminal or axillary, bisexual, mostly with a few ♀ flowers below a short spikelike raceme of ♂ flowers. Disk (of lobes or separate glands) usually present in ♂ or ♀ flowers or both. *Staminate flowers* with biseriate perianth (petals sometimes rudimentary or none); stamens equal in number to three times as many as the small or rudimentary corolla lobes. *Pistillate flowers* gamosepalous (calyx 5- to 9-lobed), apetalous; ovary (2- or) 3-celled, each locule with 1 ovule; styles equal in number to carpels, bifid or 2 or 3 times dichotomous. *Capsule* with 1 seed per carpel (or in *C. monanthogynus* fewer-celled and 1-seeded by abortion), usually pubescent. *Seeds* smooth, usually glossy, carunculate.

A large but natural genus of 600 to 800 species of herbs, shrubs, and trees, two-thirds of which are South and Central American or West Indian; represented in southern Wisconsin only by three widespread taprooted annual weeds. A fourth, entire-leaved southeastern U.S. species, with 3 styles, erect capsules, and plumply lenticular seeds about 4 mm broad, *C. capitatus* Michx., has been collected at Poynette as an accidental introduction among sweet potato vines shipped in from Tennessee (*Kelton 3,* ca. 1 Sep 1955 [fl, fr], WIS).

KEY TO SPECIES

A. Plants dioecious; staminate flower apetalous; styles 3, repeatedly dichotomous; very rare adventive. . . . . 1. *C. TEXENSIS.*

AA. Plants monoecious; staminate flowers with small petals; styles 2 or 3, deeply bifid.

B. Leaves crenate-serrate; leaf blade with 1 or 2 minute glands on lower surface near junction with petiole; styles 3 (stigmas 6 per flower); mature capsule 3-seeded; uncommon in disturbed sand prairies. . . . 2. *C. GLANDULOSUS.*

BB. Leaves entire; leaf blade without glands; styles 2 (stigmas 4 per flower); mature capsule 1-seeded; rare adventive. . . . . 3. *C. MONANTHOGYNUS.*

1. Croton texensis (Kl.) Muell.-Arg. Skunkweed, Texas croton Map 1.

Dioecious, canescent-stellate, dichotomously branched *HERB* 0.3–15 (usually 2–8) dm tall. LEAVES linear-oblong to oblong-lanceolate, 2–8 cm long, entire. STAMINATE PLANTS smaller and with narrower leaves than pistillate ones, usually with numerous flowers: *sepals 5, petals 0,* and stamens 8–12. PISTILLATE PLANTS with fewer flowers, 1–5 in each short raceme: *petals 0, styles 3, each divided nearly to the base into 4 or more branches.* Mature CAPSULES 4–6 mm long, 3-carpellate, stellate-tomentose.

Dry prairies and waste areas in sandy loam from Ala. to Tex., Ariz. and nw. Mex., north to Wyo., S.D. and Ill., occasionally adventive as far east as N. Engl., in Wisconsin still known only from a single old collection (plant staminate; undoubtedly a waif): Milwaukee Co.: railroad tracks by the Kinnickinnic River, Milwaukee (*Bennetts s.n.,* 4 Sep 1899 [fl], MIL).

2. Croton glandulosus L. var. septentrionalis Muell.-Arg. Sand croton Map 2, Fig. 2.

Coarsely stellate-pubescent annual HERBS 0.5–5 dm tall, usually branched. LEAVES petiolate; stipules minute; *blades* 3–8 cm long, oblong to narrowly ovate or lanceolate, *serrate, with 2 subsessile whitish glands on the abaxial surface near the junction with the petiole.* INFLORESCENCE terminal, often overtopped by 2–4 lateral branches, usually with 3–5 subsessile ♀ flowers at the base of a short (ca. 10 mm long) spike of ♂ flowers. STAMINATE FLOWERS 4- or 5-merous, the petals white, small but sometimes conspicuous, the stamens 7–9 (or more?). *PISTILLATE FLOWERS with* 5 sepals and *5 minute petals,* the ovary 3-carpellate, the *styles 3, bifid* almost to base. CAPSULE subglobose,

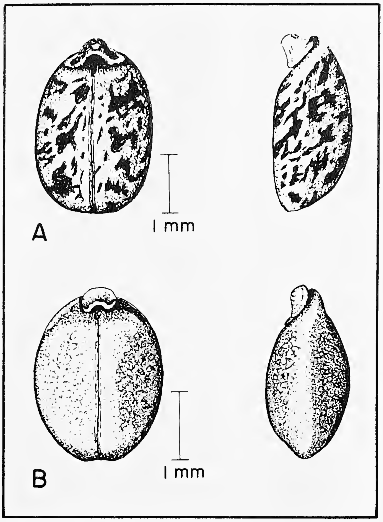


Fig. 2. Seeds of Wisconsin Crotons: A) Croton glandulosus; *B)* C. monanthogynus. *Adaxial (ventral or raphal) view (left) and lateral view with raphe on the left and micropyle up (right).*

4–5 mm long. SEEDS broadly oblong, 3–3.5 mm long, grayish-tan mottled with black, the surface minutely reticulate and somewhat shiny; caruncle well developed.

Widespread in eastern N. Am. (N.J. to Wis., Ia. and Kans., south to Fla., w. Tex., and n. Mex.), a native of dry open sandy woods, prairies, and plains, and adventive in cultivated fields and roadsides, in Wisconsin essentially confined to dry sandy plains on old terraces of the Mississippi and Wisconsin rivers, occurring in sunny open habitats, especially in disturbed sand prairies (with *Bouteloua hirsuta*), margins of blowouts (with *Euphorbia corollata* and *Hudsonia tomentosa*), and sand pits, such as at Bagley, Grant Co., with *Polanisia dodecandra, Cenchrus longispinus,* and *Triplasis purpurea* (*Nee 5432,* WIS), occasionally on roadsides or in fallow fields, such as near Spring Green, Sauk Co., with *Cycloloma atriplicifolia, Froelichia floridana, Mollugo verticillata, Oenothera cleelandii,* and weedy grasses, including *Setaria viridis, Digitaria ischaemum,* and *Panicum virgatum* (*Cochrane 11473,* NY, WIS). Scanty herbarium material and field experience indicate that *C. glandulosus* is rare, but it can sometimes be locally abundant. It is generally thought to be native south of Wisconsin, and it was not collected in the southwestern part of our state until 1935 (Columbia Co.). The isolated Sheboygan collections are from waste places in the city (*Goessl s.n.* in 1904 and 1941, both WIS). Flowering 17 Jun to 11 Sep; fruiting 18 Jul to 7 Oct.

This species is easily recognized by the sharply dentate leaves, glands at the base of the leaf blade, and staminate flowers with only 7–9 stamens. It exhibits much variability throughout its range, and several intergrading varieties have been distinguished on the basis of hair length and density, basal gland thickness, and seed shape and size. Wisconsin specimens almost invariably have relatively dense pubescence and hence belong to var. *septentrionalis* Muell.-Arg.

3. Croton monanthogynus Michx.
Prairie-tea Map 1, Fig. 2.

Annual HERBS 1–4 dm tall, finely and densely whitish-stellate or the stems minutely rusty-glandular; stems umbellately 3- to 4-forked below, repeatedly 2- to 3-forked or alternately branched above. LEAVES petiolate, the blades oblong to ovate, 1–3 cm long; stipules minute. *RACEME* terminal, overtopped by one or rarely more laterals, *usually with a solitary ♀ flower on a short recurved pedicel* at the base of a short erect spike of ♂ flowers. STAMINATE FLOWERS with 3–5 sepals, 3–5 petals, and 3–8 stamens. PISTILLATE FLOWERS with 5 sepals and 0 petals; *ovary 2-celled,* one normal and 1-ovulate, the other usually aborting; *styles 2, each deeply bifid. CAPSULE* ovoid, 4–5 mm long, *1-seeded.* SEEDS plumply lenticular, ca. 3 mm long, dull, slightly roughened, brown, with a small caruncle.

Common in dry calcareous soil from Fla. to Tex., north to Md., O., Ill., Ia., and Kans. (also ne. Mexico), occasionally adventive farther north, apparently adventive in Wisconsin: Sheboygan Co.: coal yards, Sheboygan (*Goessl s.n.,* Jul 1903 [fl], WIS); Grant Co.: railroad, Muscoda (*Davis s.n.,* 11 Jul 1934 [fr], WIS); sand prairies between railroad and Hwy. 137, W of Muscoda (*Iltis 28,435,* 9 Jul 1978 [fl], WIS).

Specimens from Grant County are not typical *C. monanthogynus.* From that species they differ in stamen number (8–12) and stigma number (6, the 3 styles deeply bifid) and in their more fertile capsules, which are 3-carpellate and 3-seeded, and larger seeds (3–4 mm long), which are uniformly shiny brown, only slightly flattened, and prominently carunculate. In typical *C. monanthogynus* the stamens are normally 3 to 8, carpels 2, each with a deeply bifid style, capsule 1- (rarely 2-) seeded, and seeds 2.8–3.1 mm long, plumply lenticular, mottled dark brown, and with a small caruncle. These Wisconsin specimens exhibit many of the same characters found in *C. capitatus* var. *lindheimeri* (Engelm. & Gray) Muell.-Arg., a variety abundant in the se. U.S. That taxon, however, has 6–10 calyx lobes, while typical *C. monanthogynus* (and the Grant Co. material) has 5 calyx lobes and much larger seeds. Additional collections are needed to more accurately assess this situation.

2. **ACALYPHA** L. Acalypha

[Miller, L. W. 1964. A taxonomic study of the species of *Acalypha* in the United States. Ph.D. Dissertation, Purdue Univ. 198 pp.]

Annual (ours) *herbs* with clear (not milky) latex, sparingly to much-branched. *Leaves* alternate, crenate to serrate or entire, with 2 prominent lateral veins from the base. *Inflorescences* spicate; flowers unisexual, the *staminate* very small, apetalous, clustered in small axillary spikes borne on a short peduncle, the *pistillate* 1–3 at base of same spike or occasionally in separate ones, surrounded by a variously lobed foliaceous bract. Disk none. Ovary 3-locular, each locule with a single ovule; styles 3, lacerate almost to base. *Capsule* usually 3-seeded, enveloped by the slightly accrescent bract. *Seeds* minutely pitted or roughened in rows, caruncular.

A largely New World genus throughout temperate and tropical regions, with about 390 species of annuals, perennials, and subshrubs. Of the 17 species occurring in the U.S., only two are known in Wisconsin.

KEY TO SPECIES

A. Pistillate bracts deeply cut into 6–9 narrowly lanceolate lobes; principal cauline leaves rhombic-ovate, crenate-serrate; stems densely (above) to sparsely (below) pubescent with recurved hairs; common native. . . . . 1. *A. RHOMBOIDEA*.

AA. Pistillate bracts mostly with 9–14 ovate or deltoid shallow lobes; leaves narrowly ovate to broadly lanceolate, slightly crenate to entire; stem with moderately dense incurved or ascending short hairs; rare adventive. . . . . 2. *A. GRACILENS*.

1. Acalypha rhomboidea Raf.
Three-seeded Mercury Map 3, Fig. 3.

Sparsely puberulent annual HERB, 1–4 dm tall, sparingly branched. *LEAVES ovate to rhombic,* 2–8 cm long (mostly smaller), *serrate, glabrate;* stipules inconspicuous; *petioles from one-third to equalling the length of the blade.* INFLORESCENCE small, axillary; pistillate *bracts* 1-3 near the base of each spike, 7–15 mm long, *cut over one-half their length into 5–11 (primarily 7–9) oblong to lanceolate lobes,* usually turning reddish with maturity (particularly the lobes). STAMINATE SPIKES rarely exceeding ♀ bracts, 1.5 cm or less long, bearing 3–9 minute apetalous flowers. PISTILLATE FLOWERS apetalous, 1–3 per bract; ovary 3-locular, each cell with 1 ovule. CAPSULE ca. 2 mm in diameter, pubescent and often glandular at apex. SEEDS ovoid, 1.2–1.7 mm long, brownish or grayish with mottling, with a somewhat shiny minutely roughened surface and a small caruncle.

Distributed over most of the eastern half of N. Am., from s. Que. to Man., south to Tex. and Fla., in Wisconsin common, occurring mostly south of the Tension Zone in a variety of moist to dry

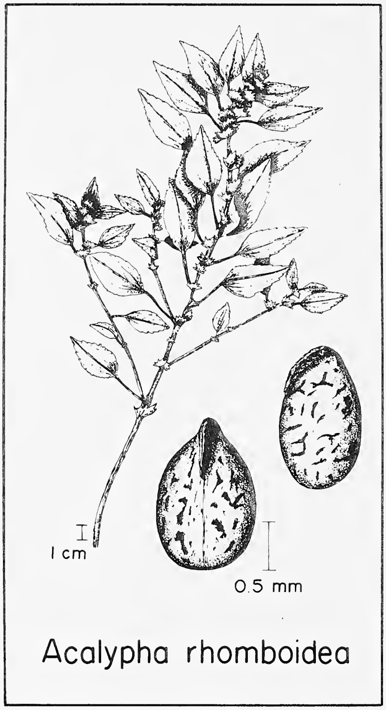


Fig. 3. Habit drawing and seed (ventral and lateral views) of Acalypha rhomboidea.

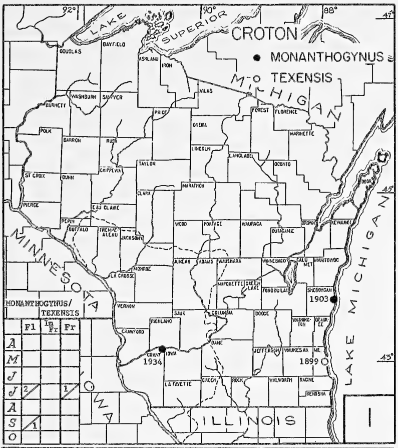
habitats, including mesic woods, river bottoms, and grassy meadows, and as a weed of disturbed ground in farm yards, cities, gardens, fields, pastures, roadsides, ditches, and on stream and pond margins, especially on fill or spoil. Flowering 2 Jul to 2 Sep; fruiting 8 Aug to 24 Oct.

Specimens of *A. rhomboidea* have frequently been misidentified as *A. virginica,* a southern species reaching the Midwest (Ind., Ill., Ia., Mich.) but not yet collected in Wisconsin. *Acalypha virginica* has bracts with 9–12 sharply acute lanceolate lobes; the leaves are narrowly ovate to lanceolate; and the stems and bracts bear long straight hairs. These two species and the next are not always easy to separate.

2. ACALYPHA GRACILENS A. Gray spp. GRACILENS
Slender Mercury Map 4.

Annual HERBS 1–4 dm tall, *sparingly pubescent with short incurved or ascending hairs;* branches slender, somewhat lax to ascending. *LEAVES narrowly ovate-lanceolate to elliptic,* 1.5–4 cm long, pubescent with short stiff appressed hairs; *petioles to 1.5 cm long, less than one-fourth the length of the blade.* SPIKES with 1–3 ♀ flowers near the base, their *bracts* in fruit 5–10 mm long, *cut one-fourth or less their depth into 8–16 lanceolate or deltoid acute to rounded lobes,* pubescent with short stiff hair and usually sessile and long-stalked glands as well. CAPSULE sparsely pubescent and occasionally glandular at apex. SEEDS 1.2–1.6 mm long, golden brown or mottled, the shiny surface with minute pits or regularly roughened in rows.

Native farther south, rare and probably adventive in Wisconsin: Sheboygan Co.: waste places, Sheboygan *(Goessl s.n.,* 29 Aug 1920 [fl], WIS); Green Lake Co.: open red cedar woods, Marquette (*Shinners s.n.,* 30 Jul 1938 [fl], WIS); pastured sandy gravelly slope, same location as Shinners' (*Zimmerman 3625,* 9 Sep 1951 [fl], WIS); Buffalo Co.: weedy pasture bordering Buffalo River (*Hartley 5224,* 8 Aug 1958 [fl], IA-photos MIL, MIN, RIVE, WIS). Hartley's collection bears a close resemblance to the narrow-leaved form of *A. rhomboidea.* Miller (1964) indicated that *A. gracilens* is the only species in the *A. virginica* complex that is common on the Coastal Plain, saying "that the disjunct occurrences in the mid-west reflect their being transported into these areas and are not a part of the true range of this species."


CROTON
● MONANTHOGYNUS
o TEXENSIS
LAKE SUPERIOR
MICHIGAN
MINNESOTA
IOWA
ILLINOIS
LAKE MICHIGAN
1903
1934
1899
MONANTHOGYNUS/TEXENSIS
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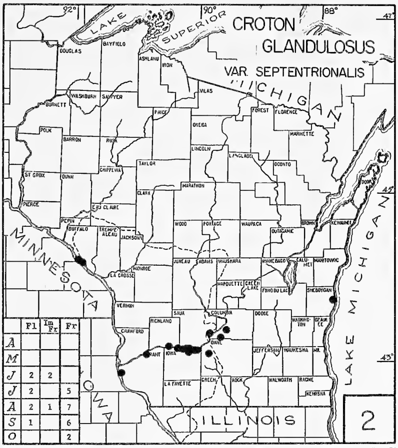
CROTON GLANDULOSUS
VAR. SEPTENTRIONALIS
LAKE SUPERIOR
MICHIGAN
MINNESOTA
IOWA
ILLINOIS
LAKE MICHIGAN
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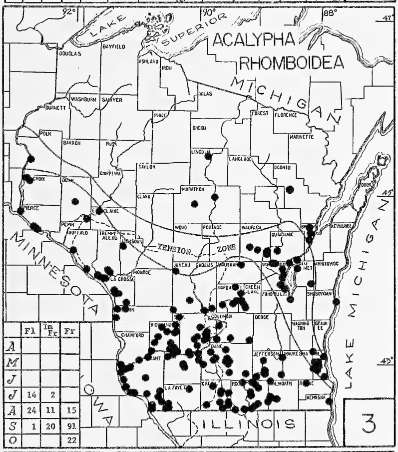
S 1 6
O 2
2


ACALYPHA RHOMBOIDEA
LAKE SUPERIOR
MICHIGAN
MINNESOTA
TENSION ZONE
IOWA
ILLINOIS
LAKE MICHIGAN
Fl Im Fr Fr
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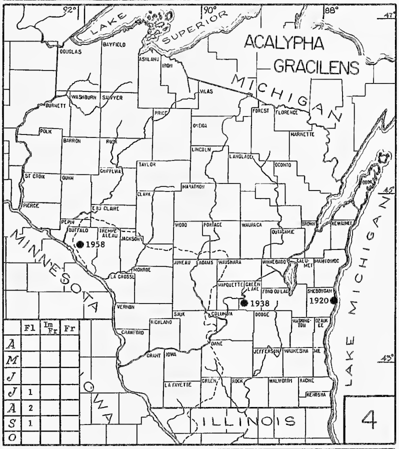
ACALYPHA GRACILENS
LAKE SUPERIOR
MICHIGAN
MINNESOTA
1958
1938
1920
IOWA
ILLINOIS
LAKE MICHIGAN
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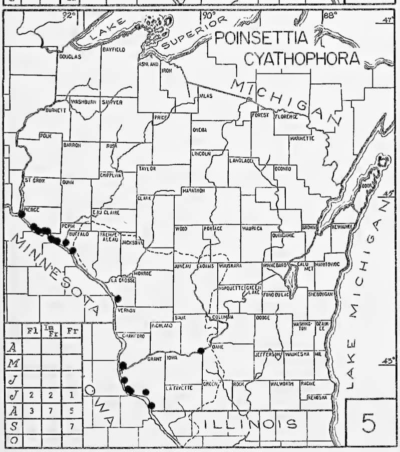
POINSETTIA CYATHOPHORA
LAKE SUPERIOR
MICHIGAN
MINNESOTA
IOWA
ILLINOIS
LAKE MICHIGAN
Fl Im Fr Fr
A
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J
J 2 2 1
A 3 7 5
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O
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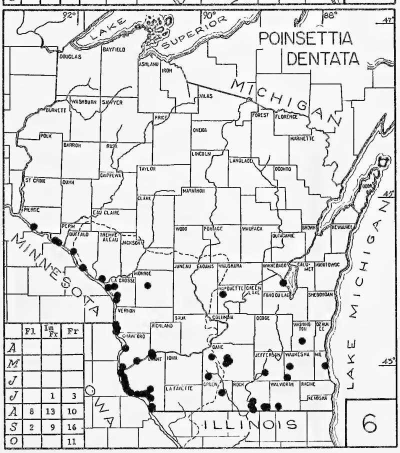

POINSETTIA DENTATA
LAKE SUPERIOR
MICHIGAN
MINNESOTA
IOWA
ILLINOIS
LAKE MICHIGAN
Fl Im Fr Fr
A
M
J
J 1 3
A 8 13 10
S 2 9 16
O 11
6

3. **POINSETTIA** Graham
Summer poinsettia, fire-on-the-mountain
Euphorbia subgen. *Poinsettia* (Graham) House

[Dressler, R. L. 1961. A synopsis of *Poinsettia* (Euphorbiaceae). Ann. Missouri Bot. Gard. 48: 329–341.]

Annual *herbs* with milky latex in all parts. *Leaves* alternate near base or opposite or subopposite throughout, petiolate; stipules minute or absent. *Cyathia* in terminal condensed dichasia or pleiochasia; involucre 5-lobed, with a single exappendiculate gland (glands rarely 2 to 5 on early cyathia), enclosing 5 cymules of ♂ flowers at the base of a solitary terminal ♀ flower. *Staminate flowers* numerous, naked. *Pistillate flowers* naked; ovary 3-celled; styles 3, joined at base, bifid for part of their length. *Capsule* 3-celled; *seeds* 1 in each cell, variously roughened; caruncle small or absent.

A New World genus of 11 or 12 species, primarily characterized by its reduced number of deeply cup-shaped exappendiculate glands, condensed terminal dichasial or pleiochasial inflorescences and tuberculate seeds. The cultivated Christmas poinsettia, *Poinsettia (Euphorbia) pulcherrima* (Willd. ex Kl.) Graham, a familiar pot and seasonal garden plant, differs from the wild poinsettias in Wisconsin by being somewhat woody, having considerably larger cyathia and seeds, and displaying many showy white, pink, or red bracts.

KEY TO SPECIES

A. Plants glabrous or with soft pubescence on upper parts; leaves all or mostly alternate, generally with two distinctly different shapes, the cauline leaves narrowly lanceolate to linear, entire, glabrous above, the bracts and bracteal leaves usually lobed or panduriform, typically red at base. . . . . 1. *P. CYATHOPHORA.*

AA. Plants usually strigose-hirsute, especially above; leaves all opposite or subopposite, relatively uniform in shape throughout, the cauline leaves ovate to linear, serrate, sparsely pubescent on both surfaces, the bracts and bracteal leaves green and typically mottled with red spots, usually cream-colored at base. 2. *P. DENTATA.*

1. Poinsettia cyathophora (Murr.) Kl. & Gke.

Map 5, Fig. 4.

Painted spurge, painted-leaf

Euphorbia heterophylla of most American authors, not L.

Euphorbia heterophylla var. *graminifolia* (Michx.) Englm.

Poinsettia heterophylla (L.) Kl. & Gke.

Essentially glabrous annuals 3–4 (rarely 10) dm tall; stem erect, branched. *LEAVES alternate near base of plant,* often opposite above; blades variable in size and shape, pandurate, ovate, lanceolate or linear, often assorted on one plant or in the same population, mostly 5–10 cm long, *usually minutely hairy beneath; bracts or leaves* green or *often splashed with red at base,* especially in recent escapes from cultivation. CYATHIA in terminal clusters of 1 to 10, pedicellate; *gland or glands* bilabiate, *sessile,* somewhat appressed to the cyathium. CAPSULE 3–4 mm long, glabrous; *SEEDS* broadly elliptic-ovoid to subglobose, *2.5–3.0 mm long, scarcely angled,* the reddish- to blackish-brown coat finely and sharply tuberculate; caruncle minute or absent.

Native to eastern U. S. and Mexico, now a widespread weed in Tropical and Temperate America and parts of the Old World, in Wisconsin highly variable and much less common than *Poinsettia den-*

tata, with which it sometimes grows. It is found primarily in the Mississippi and Wisconsin river valleys, possibly as a native in sandy woodland on shores (at Lake Pepin) but mostly as an adventive on roadsides, railroad tracks, and in dry weedy places, rarely in disturbed prairies; formerly grown in old-fashioned gardens in the southeastern counties, but apparently not escaped there. It was collected as early as 1861 at Lake Pepin on the Wisconsin side (*T. J. Hale s.n.,* WIS-2 sheets), again at several places along the Mississippi from 1910 to 1914, and about a dozen times since. Flowering (late June) 13 Jul to 26 Aug; fruiting 31 Jul to 27 Sep.

Very variable in vegetative characters, especially in leaf shape and coloration, this species has often been subdivided into varieties or additional species. Plants with mostly unlobed, linear to lanceolate cauline and rameal leaves (var. *graminifolia*) intergrade freely with those whose cauline leaves are ovate to narrowly obovate or pandurate and whose floral leaves may be of either broad or narrow shapes (var. *cyathophora*). It does not seem reasonable to treat plants as distinct varieties based on foliar polymorphism.

This species has long been known as *Poinsettia (Euphorbia) heterophylla,* a name which according to Dressler (1961) should be applied to a tropical American plant whose range hardly extends north of the frost line in Louisiana and Texas.

2. Poinsettia dentata (Michx.) Kl. & Gke. Map 6, Fig. 4.
   Toothed spurge
   Euphorbia dentata Michx.
   Euphorbia cuphosperma (Engelm.) Boiss.
   Euphorbia dentata f. *cuphosperma* (Engelm.) Fern.
   Poinsettia cuphosperma (Engelm.) Small

Annuals, 2–5 dm tall, the *stem, branches and petioles often strigose-hirsute,* especially toward the tips. *LEAVES opposite or* the upper *subopposite,* petiolate, the blades narrowly ovate to linear, 1–5 cm long, irregularly serrate, *sparsely pubescent on both surfaces; bracteal leaves green* (never red) or *occasionally white or splashed with purple.* CYATHIA in congested terminal cymes of 1 to 10, subsessible, the *gland or glands* bilabiate, *short-stalked* but appressed. CAPSULE 2–3 mm long, 4–5 mm thick, glabrous to lightly strigose; *SEEDS* broadly ovoid to subglobose, (2.2) *2.3–2.6 mm long, inconspicuously 4-angled,* finely and sharply tuberculate, the coat whitish to brown or black; caruncle ca. 0.5 mm long.

Throughout most of the temperate U. S. from Ill. to S.D. and Wyo., east to N.Y. and Va., south to Tex. and Ariz. (also Mex. and possibly Guatemala), native primarily on the Great Plains, locally common in southwestern Wisconsin, sporadic eastward, in dry sandy, gravelly or cindery soil along roads and railroads and in quarries and vacant lots, also on margins of cultivated fields, gravelly hillsides and rocky prairies. This species rarely occurs on very dry limestone (dolomite) bluffs in the Driftless Area, where it appears as if native in prairie remnants virtually free of weeds. However, natural disturbance is always present on these steep rocky prairies, and *P. dentata* is probably adventive rather than native in this ecologically "open" habitat. Significantly, most early Wisconsin collections date from the 1920's and 1930's with the earliest collections dating from 1915 (Lynxville, *Denniston s.n.,* 31 Aug, 1 Sep, both WIS). Flowering from the end of June to 21 Sep; fruiting 18 Jul to 21 Oct.

This species exhibits tremendous variation, particularly in leaf form, and some of these extremes have been given infraspecific or even specific rank. The most distinctive variant is *P. dentata* var.

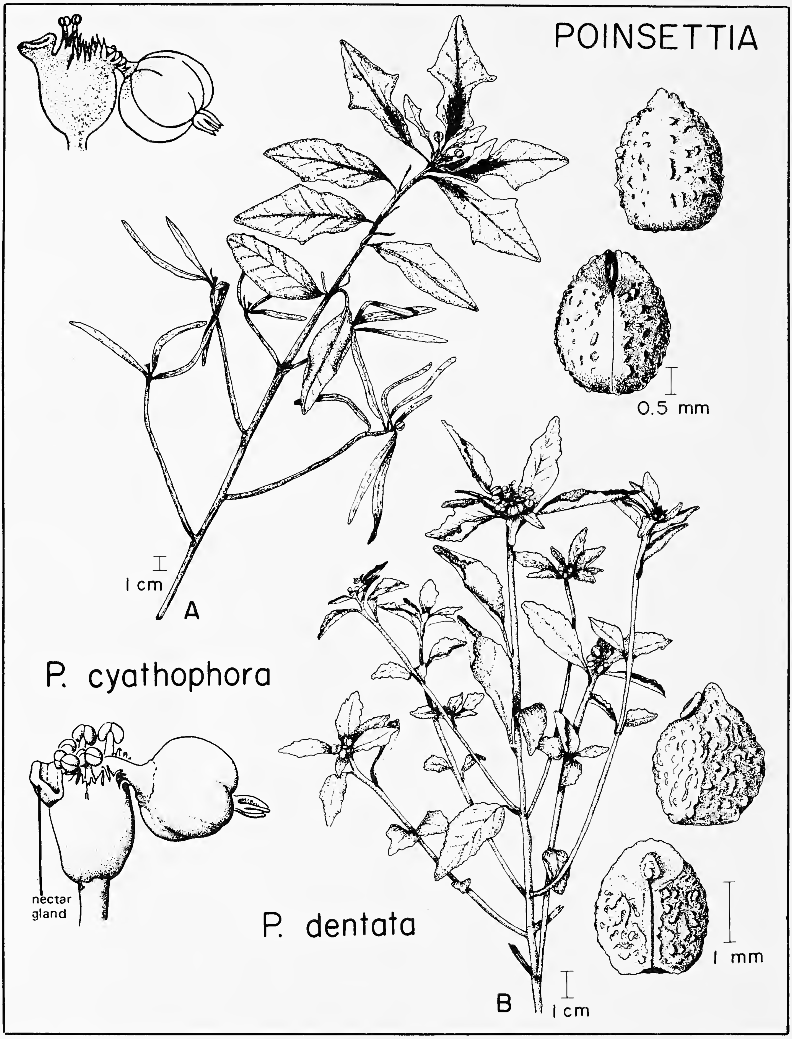


Fig. 4. Habit drawings of Wisconsin Poinsettias: A) Poinsettia cyathophora; *B)* P. dentata. *Left, cyathium, and right, seeds, of respective species. (The cyathium of* P. cyathophora *is redrawn after Dressler 1961, p. 331.)*

cuphosperma, characterized mainly by its narrow leaves, strigose capsules and less strongly tuberculate seeds. Herbarium material from not only Wisconsin and Minnesota but also the Great Plains as well as several individual populations examined during field work for this report show complete intergradation from the occasional narrow-leaved form to the more typical broad-leaved form (Richardson, 1968 & unpubl. data). Likewise, seed and capsule variants intergrade completely. The reported correlation of strigose capsules with narrow leaves versus glabrous capsules with typical leaf shapes failed completely, because in many specimens with typical var. *dentata* leaves the fruits were pubescent. Plants with strigose capsules occur sporadically and nearly coextensively with other character phases. Furthermore, the amount of pubescence varies in accord with the relative state of capsule maturity on the same plant. In the absence of character correlations it seems rather hopeless to separate our plants into more than one taxon. However, Dressler (1961) indicates that polyploidy is correlated with morphology and that the species does show clinal patterns of variation northward from centers in the Southwest and Mexico.

4. **CHAMAESYCE S. F.** Gray Spurge
Euphorbia subgen. *Chamaesyce* Raf.

[Wheeler, L. C. 1941. *Euphorbia* subgenus *Chamaesyce* in Canada and the United States exclusive of Southern Florida. Rhodora 43:97–154, 168–205, 223–286. Reprinted as Contr. Gray Herb. 136.]

Small, often prostrate annual *herbs* with milky latex in all parts, variously pubescent or essentially glabrous. *Leaves* strictly opposite, petiolate, inequilateral at base, with small interpetiolar stipules. *Cyathia* terminal but appearing axillary, solitary or often clustered; involucre with 5 lobes and 4 glands, with or without obvious petaloid appendages, enclosing 5 cymules of ♂ flowers at the base of a solitary terminal ♀ flower. *Staminate flowers* few to many, maturing serially, naked, monandrous. *Pistillate flowers* pedicellate, naked or with a pad of tissue representing a vestigial calyx; ovary 3-celled, each cell with 1 ovule; styles 3, free or joined at base, bifid for part of their length. *Capsule* 3-seeded; *seeds* small, with a smooth or variously textured surface, ecarunculate.

A genus or roughly 150–250 species, worldwide but with the majority in the New World, represented in Wisconsin by widespread species, all of which occur in open, usually disturbed, dry or less often moist soil.

KEY TO SPECIES

A. Capsules (and ovaries) strigose; stems villous. . . . . 1. *C. MACULATA.*
AA. Capsules glabrous; stems glabrous or ± pubescent (often with only fine incurved hairs).
- B. Leaves entire; seeds terete, smooth (cellular-reticulate under high magnification), the coat usually white.
  - C. Capsule ca. 3–3.5 mm long; seeds cuneiform-ovoid (i.e., compressed), 2.3–2.6 mm long; plants of Lake Michigan shore. . . . . 2. *C. POLYGONIFOLIA.*
  - CC. Capsule 1.5–1.8 mm long; seeds ovoid (not compressed), 1.3–1.6 mm long; plants widely distributed in western Wisconsin. . 3. *C. GEYERI.*
- BB. Leaves serrulate (at least toward apex or along one side); seeds angular, smooth, punctate or ridged, the coat usually brown or blackish.
  - D. Stems pubescent, at least near tips; leaves relatively large (usually more than 10 mm long), toothed along both margins.
    - E. Stems erect or ascending, glabrate or crisp-puberulent above,

tending to be pubescent in lines except at the tips; mature leaves usually more than 15 mm long; capsules mostly 1.8–2.3 mm long; stipules entire or toothed. . . . . 4. *C. NUTANS.*

EE. Stems wide-spreading or prostrate, sparsely pilose or hirsute, equally pubescent all the way around; mature leaves mostly less than 15 mm long; capsules 1.5–1.8 mm long; stipules laciniate. . . . . 5. *C. VERMICULATA.*

DD. Stems glabrous; leaves small (mostly less than 10 mm long), toothed only near apex and along one side toward base.

F. Leaves usually linear-oblong, serrulate, obtuse at apex; seeds with 3–7 evident transverse ridges and furrows on each facet. . . . . 6. *C. GLYPTOSPERMA.*

FF. Leaves usually oblong to ovate, entire in lower ⅔, serrulate at the truncate apex; seeds smooth or punctate or with a few faint transverse wrinkles. . . . . 7. *C. SERPYLLIFOLIA.*

1. CHAMAESYCE MACULATA (L.) Small
Map 7, Fig. 5.
Wartweed, milk-purslane
Euphorbia maculata L.
E. supina Raf.
Chamaesyce supina (Raf.) Raf.

Prostrate (usually) to ascending annual *HERBS,* sparsely to densely *villous throughout.* LEAVES oblong to elliptic- or oblong-ovate, 1–2.5 cm long, often with a red-purple blotch, slightly serrulate; stipules distinct, 2- or 3-toothed or cleft. CYATHIA solitary on branches of condensed laterals; glands transversely elliptic, very small, with minute to evident, white or pink appendages. CAPSULE ovoid, 1.3–1.6 mm long, the angles obtuse; seeds oblong-ovoid, 0.8–0.9 (1.2) mm long, 4-angled, *each facet traversed by* 3–5 ± regular *low transverse ridges,* these often passing through the angles; coat tan with white covering.

Native of e. U.S. and s. Canada, now very common is disturbed or waste places from N.S. and s. Que. to N.D., s. to Fla. and e. N.Mex., introduced on the West Coast and in Eu., one of the most abundant weeds in Wisconsin on gravelly and sandy road shoulders, railroad embankments, fallow or cultivated fields, lawns and gardens, and waste ground, also in pastures, open woods, sand prairies, and shores. In addition, this species has the ability to utilize even the rather unique habitat offered by cracks in sidewalks and driveways, and it is commonly associated with other prostrate species of dry barren places (e.g., *Chamaesyce glyptosperma, Mollugo verticillata* and *Polygonum aviculare*). While Fassett (1933) suggested that in northern Wisconsin this species is replaced by *C. glyptosperma,* herbarium collections and field observations indicate that, although the range of the two in the state is very similar, *C. maculata* is the common species in the North. Flowering 12 Jun to 24 Aug with some continuing until frost; fruiting (18 Jun) 4 Jul to 21 Oct or until frost.

This species has had a tortured nomenclatural history. In his excellent study Wheeler (1941) applied *Euphorbia supina* Raf. to it, and his conclusions were adopted by a number of authors, including Fosberg (1953). According to Croizat (1962) and Burch (1966a), however, the epithet *maculata* (=*supina*) must be applied to the prostrate species and the epithet *nutans* to the larger upright one.

An old specimen (*Schuette s.n.,* 1889, F) from Brown Co., cited by Fassett (1933, p. 182) as *Euphorbia humistrata,*

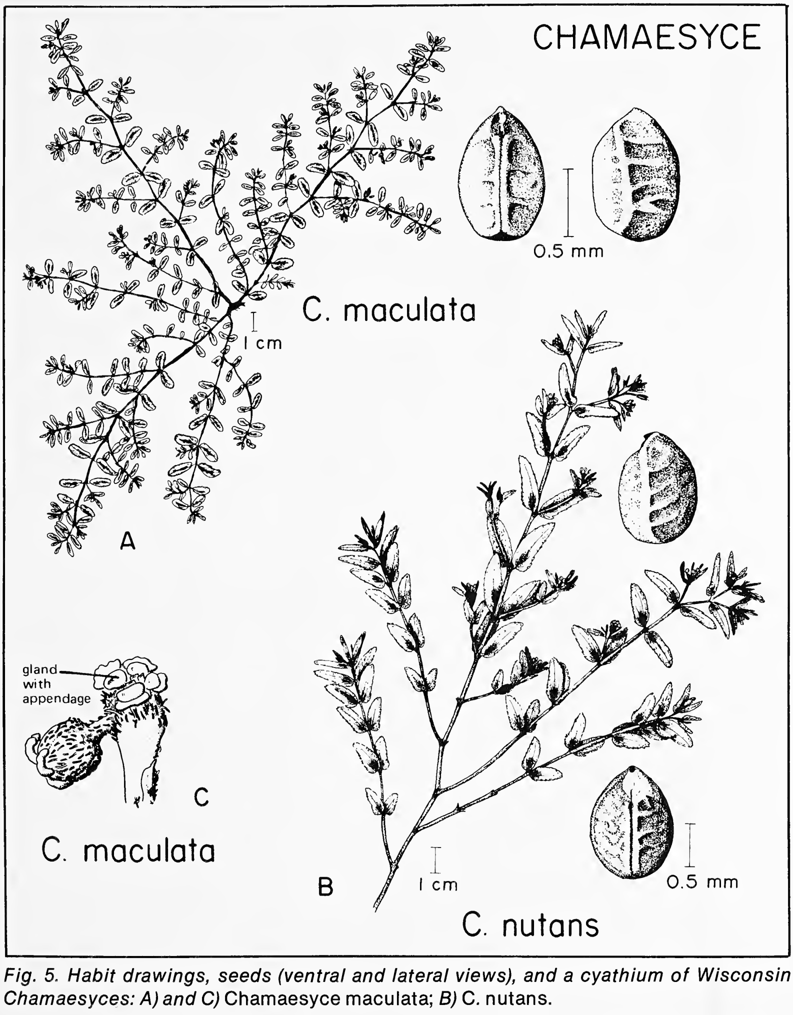


Fig. 5. Habit drawings, seeds (ventral and lateral views), and a cyathium of Wisconsin Chamaesyces: A) and C) Chamaesyce maculata; *B)* C. nutans.

has been annotated as *Chamaesyce maculata.*

2. Chamaesyce polygonifolia (L.) Small — Map 8, Fig. 7.
Seaside spurge
Euphorbia polygonifolia L.

Prostrate, somewhat fleshy annual HERBS forming open mats to 4 dm in diameter, glabrous in all parts. *LEAVES narrowly oblong to oblong-lanceolate,* 5–15 mm long, slightly inequilateral at base, *entire;* stipules deeply 2- to 3-parted or rarely entire or toothed. *CYATHIA*

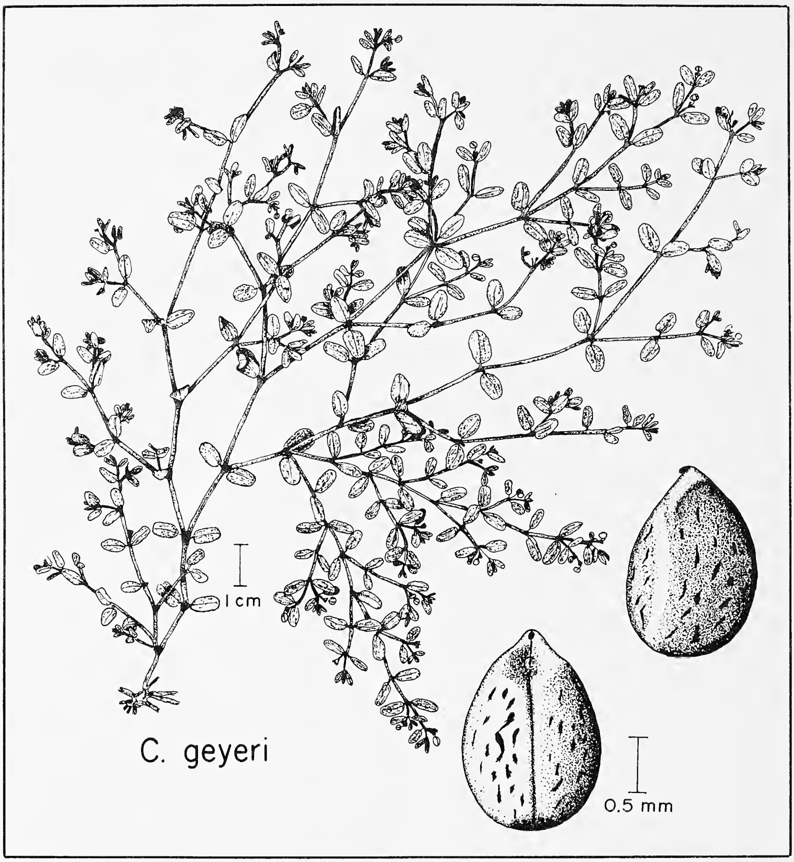


Fig. 6. Habit drawing and seed (ventral and lateral views) of Chamaesyce geyeri.

solitary on branches of short upper laterals; *glands* 4 or often obsolete, broadly oval to suborbicular, *with at most rudimentary appendages. CAPSULE* truncate-ovoid, *relatively large, 2.9–3.6 mm long,* the angles obtuse to rounded. *SEEDS* cuneiform-ovoid, *2.3–2.6 mm long,* the facets slightly (ventral side) to strongly (dorsally) rounded, smooth, whitish-gray.

A characteristic species of sand dunes and sandy or gravelly upper beaches or strands of the Atlantic and Gulf coasts (from e. Que. and N.S. south to n. Fla., also in La.), disjunct to the shores of the Great Lakes (except Lake Superior) in s. Ont. (north to the Bruce Peninsula, Lake Huron), Mich. and Wis., also naturalized in w. Eu. (cf. maps in Cain 1944, Guire & Voss 1963, McLaughlin 1932, Peattie 1922, Wheeler 1941), in Wisconsin restricted to the sand beaches of Lake

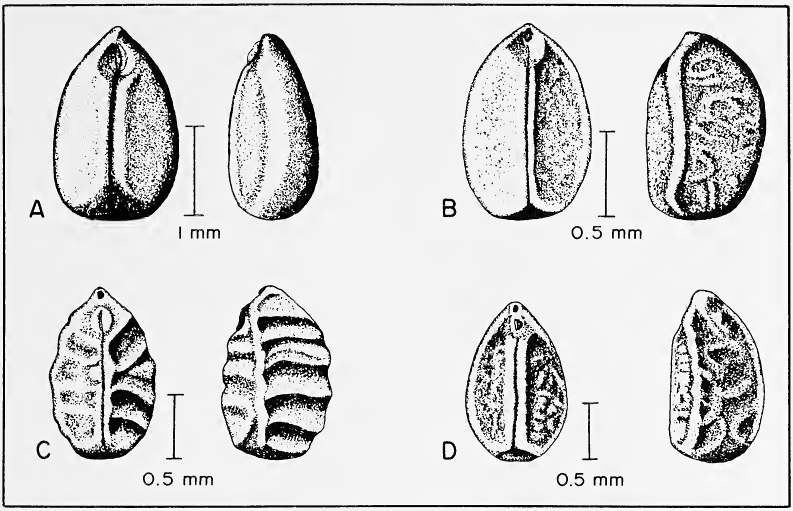


Fig. 7. Seeds of Wisconsin Chamaesyces: A) Chamaesyce polygonifolia; *B)* C. vermiculata; *C)* C. glyptosperma; *and D)* C. serpyllifolia. *Ventral (adaxial) view (left) and lateral view with raphe on the left and micropyle up (right).*

Michigan from Door to Kenosha counties. *Chamaesyce polygonifolia* grows on both the flatter lower strand relatively close to the water's edge, there associated consistently with *Corispermum hyssopifolium, Cakile edentula,* and *C. lacustris* (all likewise annuals), and the looser sand of upper beach dunes, sometimes partly buried and often associated with common dune grasses *(Agropyron dasystachyum* var. *psammophilum, Calamovilfa longifolia* var. *magna, Elymus canadensis, Poa compressa)* as well as *Cyperus schweinitzii, Juncus balticus, Prunus pumila, Oenothera parviflora,* and *Artemisia caudata.* Flowering from 6 Jul to 23 Aug; fruiting from 10 Aug to 15 Oct.

This species is listed as being threatened in Wisconsin (Read, 1976) because of its small number of stations and its dependence on a rare habitat type. During the summers of 1975 and 1976 only a relatively small number of plants were seen at Point Beach State Forest (Manitowoc Co.) and Terrae Andrae State Park (Sheboygan Co.), and later (1985) fewer yet at Sand Dunes Park on Washington Island. The species occupies a very narrow ecological zone, but, being on public land, these populations are under some protection. Additional sites in other counties need similar protection to help ensure the continued existence of not only this critical species but its associates and their rather unique habitat.

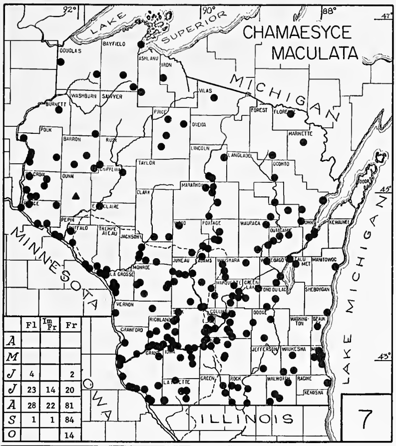
A Comment on the Phytogeography of Chamaesyce polygonifolia

The history of *Chamaesyce polygonifolia* is representative of the many species of the Coastal Plain having inland extensions to the Great Lakes area. Like the majority of such species, seaside spurge is generally distributed between the Atlantic Coast and Lake Michigan, occurring on the shores of the lower four Great Lakes and the rivers connecting them, as well as coming a short distance up the Hudson River and appearing at a single inland locality (at Onondaga Lake[2]) in the Ontario Basin. Peattie (1922) concluded that this distribution can best be explained in terms of step-wise migration westward in early post-Pleistocene times. A smaller category of Coastal Plain plants is comprised of species with limited inland distributions, including *Muhlenbergia uniflora, Echinochloa walteri,* and *Utricularia resupinata* as well as several strikingly disjunct Cyperaceae (i.e., *Rhynchospora macrostachya, Scleria reticularis, Psilocarya scirpoides, Fuirena squarrosa,* and the oft-cited *Eleocharis melanocarpa*). As for their occurrence in the Midwest, Peattie upheld his answer of the westward migration, suggesting that at the close of the glacial period the Coastal Plain flora was far more extensive than at present and that those species exhibiting geographical discontinuities were simply eliminated from the intervening areas.

Later studies, such as the exhaustive analysis of the sand barrens flora of Wisconsin by McLaughlin (1932), reinforced Peattie's explanation, albeit refining the geographical groupings of plants and giving greater consideration to habitat conditions. Post-glacial migration is a reasonable hypothesis for dune and strand plants, such as *Chamaesyce polygonifolia, Hudsonia tomentosa, Cakile edentula* (s.l.), and *Ammophila breviligulata,* which are distributed along natural avenues of suitable habitats and whose disjunctions involve only short distances.

The possibility of alternative hypotheses ought not to be excluded, however, not only for strictly Coastal Plain species, i.e., those occupying non-littoral habitats, but also for some of the strand disjuncts. According to Svenson (1927), the occurrence of maritime plants inland is generally not controlled by the limits of post-Pleistocene marine submergence. He places considerable emphasis upon transportation of seeds by human agencies and the influence of favorable sites for establishment after dispersal. In discussing *Cakile,* Rodman (1974) postulates that *C. edentula* (as *C. edentula* var. *edentula*) is an historical introduction (perhaps in ballast) to the Great Lakes shores (see also Patman & Iltis 1960, who were not aware of the recentness of this introduction) but that *C. lacustris* (as *C. edentula* var. *lacustris*) is a locally evolved endemic, its progenitors having colonized the region (by ordinary migration) from the Atlantic Coast. The widely disjunct areas of the rare, highly localized Cyperaceae mentioned above imply that these probably arrived in the Midwest via long-distance dispersal, persisting now only locally due to the presence of small special habitats. This pattern also suggests that disjunctions found among other Coastal Plain elements may also have been achieved by long-distance dispersal or a combination of dispersal and migration, as the case may be, rather than only by migration followed by range restriction. It is difficult or impossible to apply one explanation when interpreting distributional disjunctions. The same historical, climatic, and environmental factors that explain the distribution of some plants may not account for the distribution of all species, even among groups having similar geographical patterns, such as *Chamaesyce polygonifolia, Cakile edentula,* and *Cakile lacustris.* Any explanations concerning disjunctions must be settled on a case-by-case basis.

[2] This station has been listed by catalogers of the New York flora (and apparently mapped by Peattie) on the authority of an old floristic list (Goodrich, L. L. H. 1912, p. 123. Flora of Onondaga County: as Collected by Members of the Syracuse Botanical Club. McDonnell Co., Syracuse.)



	Fl	Im Fr	Fr
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M			
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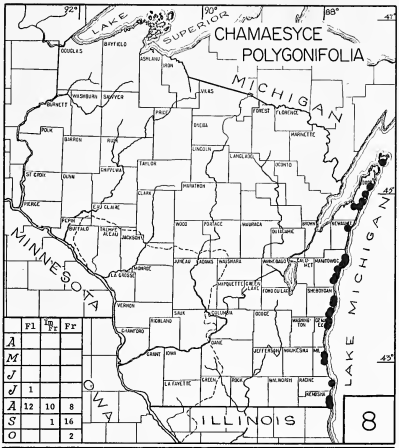
A	28	22	81
S	1	1	84
O			14



	Fl	Im Fr	Fr
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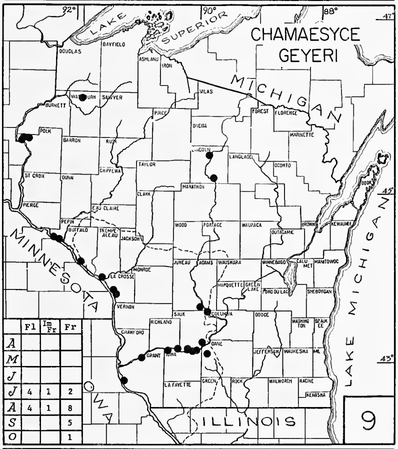
M			
J			
J	1		
A	12	10	8
S		1	16
O			2



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M			
J			
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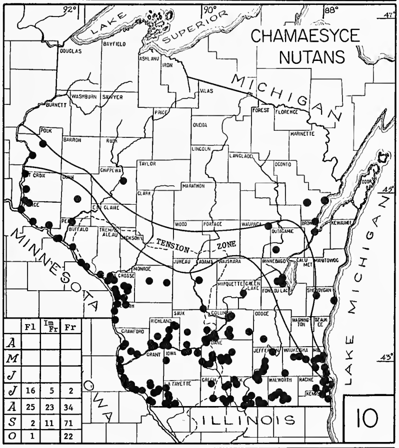
S			5
O			1



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M			
J			
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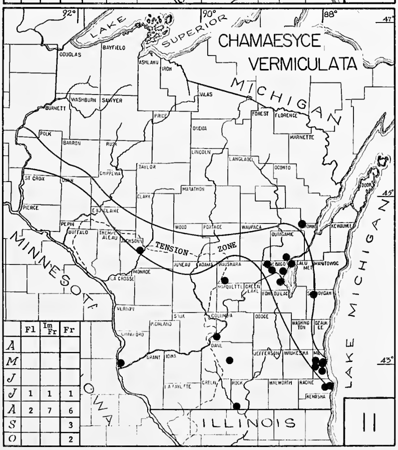
A	25	23	34
S	2	11	71
O	1		22



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M			
J			
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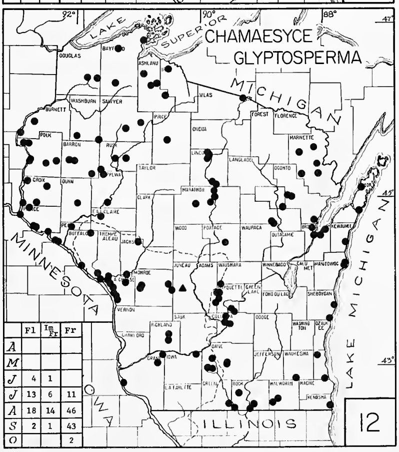
A	2	7	6
S			3
O			2



	Fl	Im Fr	Fr
A			
M			
J	4	1	
J	13	6	11
A	18	14	46
S	2	1	43
O			2

3. CHAMAESYCE GEYERI (Engelm.) Small
   Geyer's spurge Map 9, Fig. 6.
   Euphorbia geyeri Engelm.

Glabrous annual HERBS, with prostrate stems forming open mats to 4 dm in diameter. *LEAVES* ovate- to elliptic-oblong, 4–10 mm long, strictly *entire;* stipules deeply 2- to 3-parted. CYATHIA solitary on branches of short laterals; glands broadly oval to suborbicular, the appendages white, smaller than the glands. *STAMINATE FLOWERS* 1–5 (6) per fascicle, *5–27 per involucre. CAPSULE 1.5–1.8 mm long,* strongly lobed, the angles rounded. *SEEDS ovoid, 1.3–1.6 mm long,* the coat smooth, whitish to light reddish-brown or whitish with dark orange mottling due to the testa showing through.

Native to the Great Plains from N.D., Minn. and Colo.. south to n. Ind., Tex. and N.Mex., reaching its eastern range limits primarily in western Wisconsin; also adventive in Upper Mich. Aside from certain sand barrens of northwestern Wisconsin, this species is more or less restricted to the Driftless Area. It is definitely associated with sandy soil, occurring primarily near the larger rivers on dunes (usually stabilized), sand hills, and river banks (e.g., at Cruson Slough, Richland Co., with *Polanisia dodecandra* [sub *Cochrane & Lewicki 3052*] or with such colonizing grasses as *Triplasis purpurea, Eragrostis pectinacea, Elymus canadensis, Digitaria ischaemum,* and *Panicum virgatum* [sub *Cochrane & Cochrane 7083*]), blowouts and sand pits, and sandy waste areas and barrens. Although not widely distributed, *C. geyeri* does tend to be locally common, particularly in abandoned agricultural fields, margins of prairie remnants and roadsides. Flowering 12 Jul to 17 Aug; fruiting 26 Jul to 2 Oct.

Although not given protective status, this species might be deserving of reconsideration for listing once its status can be more thoroughly investigated (Read, 1976).

This species is commonly confused with *C. glyptosperma* but may be easily distinguished from the latter by the entire leaves, higher number of staminate flowers per cyathium, and smooth whitish seeds.

4. CHAMAESYCE NUTANS (Lag.) Small
   Eyebane Map 10, Fig. 5.
   Euphorbia nutans Lag.
   E. preslii Guss.
   E. maculata L. sensu Wheeler and others

Suberect to ascending annual *HERBS* 8–30 cm tall; stems mostly simple below, short-pubescent at tips and in 1 or 2 lines on young shoots, glabrate. *LEAVES* ovate-lanceolate to oblong, often somewhat falcate, *1–4 cm long, serrulate,* glabrous or sparsely long-pilose particularly beneath, typically red-mottled; *stipules* connate or distinct, triangular, *entire or toothed.* CYATHIA both solitary and clustered in lateral and terminal short-stalked compound dichasia; glands transversely elliptic to circular, the appendages obsolete or up to 3 times the width of the gland, white or pink. *CAPSULES* broadly ovoid, when mature (1.6) *1.8–2.4 mm long,* strongly lobed, the angles subacute, glabrous. SEEDS oblong-ovoid, 1.1–1.3 mm long; ventral angle rounded, the others well marked, the 4 unequal *facets* flat to slightly convex, *rippled or transversely wrinkled* by several (5–9) low irregular ridges; coat dark gray to dark brown with angles usually lighter in color.

Widespread in warm-temperate parts of the world, including eastern N. Am. and the Great Plains, from Que. to N.D., south to Fla. and Tex. (introd. in Wash., Calif.), relatively common in the southern half of Wisconsin, particularly along the Mississippi and Wisconsin rivers. Generally considered a weed, it is common in sandy, gravelly or cindery soils along railroad embankments, roadsides and dry open ground, also on flood plains, shores and ditches, disturbed spots in woods and prairies, hillsides, waste or cultivated fields, and pastures. *C. nutans* is very rare north of the Tension Zone and then only along railroad embankments or roadsides, which apparently provide temporary avenues into that portion of the state. Even once established, dispersal seems to be restricted, few, if any, plants invading adjacent areas, the populations tending to remain small. South of the Tension Zone dispersal is much more efficient or the climate more agreeable, because the species is relatively widespread and occurs in a variety of habitats. Flowering 9 Jul to 30 Aug (15 Oct); fruiting 24 Jul to 24 Oct.

Much controversy has centered around the correct name for this distinct, semi-erect glabrate species. Burch (1966a) disagreed with Wheeler's (1941) interpretation of the Linnaean *E. maculata,* indicating that due to the established usage of *E. hypericifolia* for the tropical or subtropical species, the epithet *nutans* should be applied to the upright northern species. Also, since the specimen used by Wheeler as the type for *E. maculata* was not in Linnaeus' possession until after the publication of *Species Plantarum,* the name *E. maculata* must be rejected for this species and applied to our species no. 1 (see comments under *E. maculata*).

5. Chamaesyce vermiculata (Raf.) House — Map 11, Fig. 7.
Hairy spurge
Euphorbia hirsuta (Torr.) Wieg.
E. rafinesquii Greene

Prostrate (usually) to ascending annual HERBS; *stems* to 4 dm long, *sparsely long-pilose* at least in a line on the upper side and extending down to internode from the stipules. LEAVES obliquely ovate to lanceolate, (5) 8–15 (18) mm long, glabrous or sparsely pilose above, usually pilose beneath, serrulate; *stipules* distinct or united, *usually deeply cleft.* CYATHIA solitary, the uppermost sometimes appearing clustered by the condensation of a small leafy cyme; glands long-stipitate, subcircular, the *appendages usually prominent,* white. *CAPSULE* broadly ovoid, *1.5–1.8 mm long,* glabrous or rarely pilose and glabrate, the angles rounded. *SEEDS* ovoid, 1.1–1.2 mm long, *quadrangular,* gray-brown, slightly wrinkled, the *ventral facets slightly concave,* the dorsal flat to slightly convex.

Locally common in the northeastern U.S., reaching its western range limits in Wisconsin (except for B.C., Ariz., and N. Mex., where introd.?), considered native but generally found in waste ground and disturbed sites, such as railroads, roadsides, ditches, parking lots, city streets, occasionally yards and gardens. This species is sporadic in southern Wisconsin; field observations indicate that even where *C. vermiculata* is found, individual plants are widely scattered. Flowering July through September (collected specimens: 17 Jul to 10 Aug); fruiting 5 Aug to 14 Oct.

6. Chamaesyce glyptosperma (Engelm.) Small — Map 12, Fig. 7.
Ridge-seeded spurge
Euphorbia glyptosperma Engelm.

Prostrate or ascending glabrous annual HERBS; stems 5–30 cm long. *LEAVES narrowly oblong to ovate-oblong,* 3–15 mm long, strongly inequilateral, serrulate; stipules usually connate, subulate or deeply cleft into filiform divisions. CYATHIA solitary on branches of short laterals; glands transversely elliptical, often much reduced, the appendages from shorter than to equalling the glands or absent, white to reddish. *STAMINATE FLOWERS* (0) 1–2 per fascicle, *2–7* (usually 4) *per involucre.* CAPSULE depressed-ovoid, 1.3–1.6 mm long, the angles obtuse. SEEDS oblong-ovoid, 0.9–1.0 mm long, strongly 4-angled, the *ventral facets concave, traversed by 3–5 prominent ridges,* the *dorsal facets convex, traversed by 5–7 prominent ridges,* the ridges ± passing through the angles; coat tan but appearing white due to thick bloom.

Widespread from N. Engl. south to Tex. and west to B.C. and n. Calif., in Wisconsin a very common weed of roadsides, railroads, sand or gravel pits, waste areas, and in virtually every available habitat with open, rather dry sandy, gravelly, or loamy soils: driveways, fire lanes, paths, lake shores, prairies, pine plantations, plowed fields, lawns, playgrounds, parking lots, cliffs, ledges, outcrops, and talus. It frequently occurs with *Chamaesyce maculata,* the two species apparently having very similar ecological requirements, both being well adapted to man-made disturbances and common in cracks of sidewalks or driveways, baseball diamonds, tennis courts, etc. Flowering 20 Jun to 7 Sep (October); fruiting 1 Jun to 6 Oct.

See notes under *C. geyeri* (no. 3) and *C. serpyllifolia* (no. 7).

7. Chamaesyce serpyllifolia (Pers.) Small — Map 13, Fig. 7.
   Thyme-leaved spurge
   Euphorbia serpyllifolia Pers.

Prostrate or ascending annual HERBS, glabrous in all parts; *stems* 5–30 cm long, *often* (at least the distal internodes) *flattened in the plane of the leaves. LEAVES* variable in shape, *oblong, spatulate or obovate,* 3–14 mm long, strongly serrulate above the middle, typically red-mottled above along the midrib; stipules distinct, deeply 2- or 3-parted into linear segments. CYATHIA solitary; glands transversely oblong, the appendages very small, white. *STAMINATE FLOWERS* 1–3 per fascicle, *5–12 (18) per involucre.* CAPSULE ovoid, 1.3–1.9 mm long, glabrous, the angles obtuse. SEEDS oblong-ovoid, 1.0–1.2 mm long, strongly 4-angled; *facets essentially smooth, punctate, or sometimes with faint transverse wrinkles,* the coat gray- to yellow-brown with a thick bloom.

Primarily in the western states and the northern Great Plains from B.C. east to Alta., south to Tex., N. Mex., and Baja Calif., extending east to Minn., Ia., Wis., and n. Mich.; only rarely collected in sites with undisturbed vegetation. In Wisconsin it is weedy and probably adventive, the limited number of collections (ca. 12) sporadically distributed north of the Tension Zone, most often along railroads and roadsides but rarely in other disturbed sites (i.e., drained river bed, ditch, and "dry soil"). Flowering July and August; fruiting from 19 Jul through September.

Chamaesyce serpyllifolia and *C. glyptosperma* are similar and frequently grow together. In both species the leaf blades are very variable in shape and often appear bowed-in along the sides due to the revolute margins. However, *C. serpyllifolia* tends to be relatively robust and decumbent to ascending in habit. Also, its seeds are rather smooth to somewhat rugulose, and the red-mottled spatulate to obovate leaves have the margins unthickened and serrulate for less than half the length from the apex. *Chamaesyce glyptosperma* is slender and typically prostrate. It has seeds with prominent transverse ridges and oblong to subfalcate leaves with thickened margins whose serrulations often extend to the base on the lobed (abaxial) side.

5. **EUPHORBIA** L. Spurge

Euphorbia L. subgen. *Esula* Pers.

[Richardson, J. W. 1968. The Genus *Euphorbia* of the High Plains and Prairie Plains of Kansas, Nebraska, South and North Dakota. Univ. Kansas Sci. Bull. 48:45–112.]

Erect annual or perennial *herbs* with milky latex in all parts; stems scarcely branched for much of their length, then umbellate or branching freely (sometimes dichotomously) above. *Leaves* alternate near the base, opposite or alternate above and usually verticillate below the branches (rays) of the umbel, mostly estipulate; blades in shape and character often changing serially up the stem and on the fertile branches. *Inflorescence* of cyathia, terminal, clustered or usually umbellate; cyathium 5-lobed, with 4 or 5 glands and with or without petaloid appendages, enclosing 4–5 cymules of ♂ flowers at the base of the solitary ♀ flower. *Staminate flowers* naked, few to many, maturing serially. *Pistillate flowers* naked, the ovary 3-celled, each cell with 1 ovule; styles 3, ± joined at the base and bifid for part of their length. *Capsule* 3-seeded. *Seeds* with or without a caruncle.

The largest genus in the family, with perhaps 1600 species as circumscribed by Linnaeus and later by Pax and Hoffmann (1910–1924). Some workers, appalled by the heterogeneity of this group, have suggested that *Euphorbia* s. str. should include only a few of the woody or succulent African species and that the remainder should be divided among a number of more "natural" genera. Further work may show that this course should be followed, but until other segregates can be unequivocally defined, we are accepting as distinct genera in addition to *Euphorbia* only the easily recognizable *Chamaesyce* and *Poinsettia.*

Several exotic spurges have been introduced into North America as ornamental plants. Of these, cypress spurge (*Euphorbia cyparissias* L.) and leafy spurge (*E. esula* L.) are now persistent weeds in practically every county in Wisconsin. The European *Euphorbia myrsinites* L., a perennial with glaucous fleshy stems, alternate, obovate to suborbicular leaves, and dilated, 2-horned glands, was collected at Oshkosh by Harriman (*s.n.,* 2 Jun 1971 [im fr], OSH-photos MIL, RIVE, UWM, WIS) as an adventive in his garden that did not reappear in subsequent years.

KEY TO SPECIES

A. Glands of the cyathia with conspicuous white appendages; seeds ecarunculate [subgen. *Agaloma* (Raf.) House].

- B. Capsules and involucres pubescent; seeds 3–4 mm long, tuberculate or reticulate-verrucose; upper leaves and bracts conspicuously white-variegated; plant annual [sect. *Petaloma* Boiss.]. . . . . 1. *E. MARGINATA.*
- BB. Capsules and involucres glabrous (variously pubescent when young); seeds 2–2.5 mm long, smooth or with indistinct rows of shallow depressions; all leaves green; plant perennial [sect. *Tithymalopsis* (Kl. & Gke.) Boiss.]. . . . . 2. *E. COROLLATA.*

AA. Glands of cyathia without petaloid appendages; seeds caruncùlate [subgen. *Esula* Pers.].

- C. Leaves entire; glands of involucre lunate, their tips pointed or prolonged into short horns [sect. *Esula* (Roeper) Koch].
  - D. Stem leaves broadly ovate to obovate; seeds pitted; inflorescence with usually 3 primary rays; plants annual (or short-lived perennial in *E. commutata*).
    - E. Capsule ca. 3 mm long, without keels; seeds finely and uniformly pitted on all facets, broadly carunculate. . 3. *E. COMMUTATA.*
    - EE. Capsule ca. 2.5 mm long, with 2 longitudinal keels on each lobe; seeds with 4 vertical rows of large pits on the outer facets and 2

longitudinal furrows on the inner, minutely carunculate. .... 4. *E. PEPLUS.*

DD. Stem leaves linear to linear-spatulate or lanceolate; seeds smooth; inflorescence with 5 or more rays; plants perennial.

F. Principal cauline leaves 1–3 cm long, 1–3 mm wide, densely crowded; style plus stigma shorter than the young exserted ovary; plant with many stems from strong horizontal rhizomes. .... 5. *E. CYPARISSIAS.*

FF. Principal cauline leaves 3–7 cm long, mostly 3–10 mm wide, less numerous; style plus stigma equalling or exceeding the immature capsule in length; plant with fewer stems from deeper rootstocks. .... 6. *E. ESULA.*

CC. Leaves finely serrate; glands of involucre elliptic or suborbicular [sect. *Tithymalus* Roeper].

G. Capsules verrucose; seeds lenticular, nearly smooth; floral leaves ± cordate-clasping; rays of primary inflorescences 3. 7. *E. OBTUSATA.*

GG. Capsules smooth; seeds ovoid-subglobose, conspicuously reticulate-rugose; floral leaves tapered to base; rays of primary inflorescences 5. .... 8. *E. HELIOSCOPIA.*

1. EUPHORBIA MARGINATA Pursh
Snow-on-the-mountain Map 14.

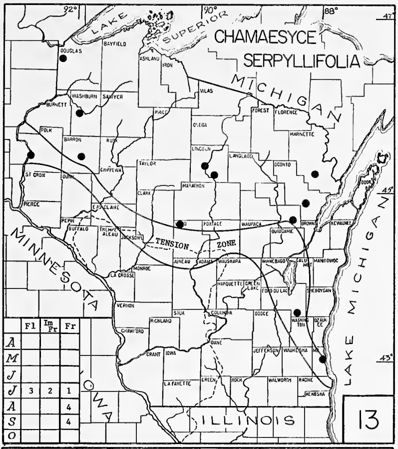
Subglabrous to densely villous (especially on younger parts) *annual HERBS;* stems 3–9 dm tall, unbranched below the rays of the terminal inflorescence. LEAVES alternate, estipulate, subsessile, the *blades* broadly ovate to elliptic, 3–9 cm long, *mucronate;* whorl of leaves at base of umbel (ray leaves) and floral leaves similar, *those pairs near the cyathia* narrower and *with broad white margins. Rays of umbel 3* (rarely 4 or 5), simple or dichotomously branched; CYATHIA with 4 (usually) or 5 oblong light to dark green glands, *each with a large white appendage* wider and longer than the gland. *CAPSULES* depressed-globose, ca. 5 mm in diameter, *pubescent.* SEEDS ovoid-globose, ca. 3–4 mm long, the white to tan coat tuberculate or reticulate-verrucose, ecarunculate.

Native from Tex. to N.M. and on the central and southern Great Plains, escaped from cultivation farther north and east, in Wisconsin cultivated for ornament and occasionally escaped in the southern half to dumps, vacant lots, roadsides, railroads, abandoned fields, farm yards, and other waste places. Flowering 27 Jul to 20 Sep; fruiting 31 Aug to 10 Oct.

Contact with the milky sap of *E. marginata* produces inflammation and blistering of the skin in many people.

2. EUPHORBIA COROLLATA L.
Maps 15, 16; Figs. 1, 8.
Flowering spurge

Glabrous or variously villous *perennial HERBS,* 3–10 dm tall, usually unbranched below. LEAVES alternate, estipulate, subsessile, the *blades* elliptic, oblong or linear, 2–6 cm long, *obtuse to retuse,* the whorl at the base of the umbel similar but usually smaller, the floral leaves opposite, smaller and narrower than the others, some with a small light-colored margin. *INFLORESCENCE* umbellate, the primary rays 3–6, usually dichotomously branched at least twice and with other branches from the upper nodes reaching the same level to form *a large corymbiform or paniculate cyme.*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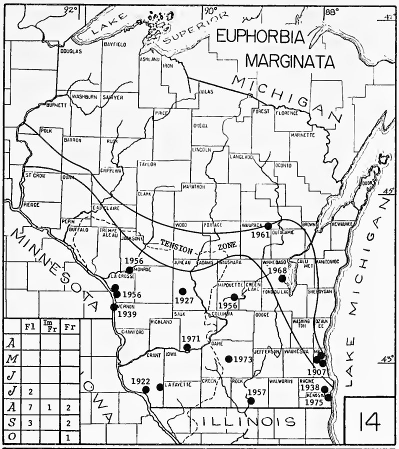
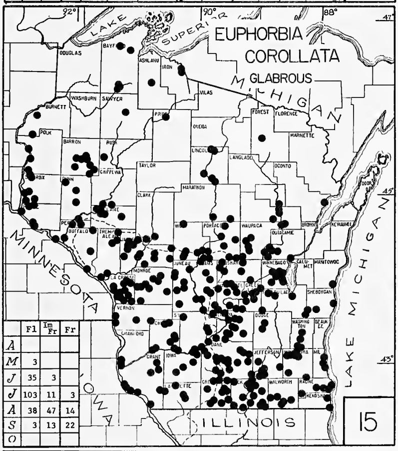
SERPYLLIFOLIA
TENSION ZONE
LAKE SUPERIOR
LAKE MICHIGAN
Fl | Im Fr | Fr
J 3 2 1
A 4
S 4
13


EUPHORBIA
MARGINATA
TENSION ZONE
1961
1956
1968
1956
1927
1956
1939
1971
1973
1922
1957
1907
1938
1975
Fl | Im Fr | Fr
J 2
A 7 1 2
S 3 2
O 1
14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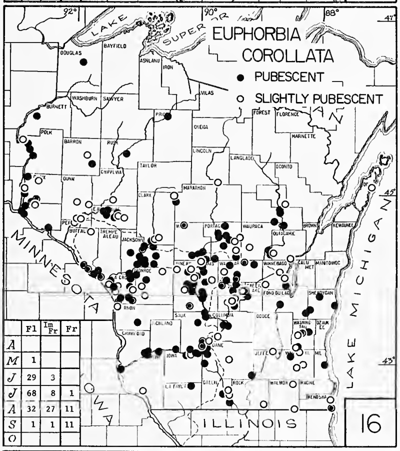
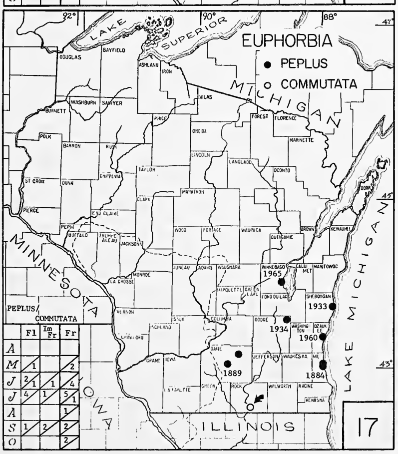
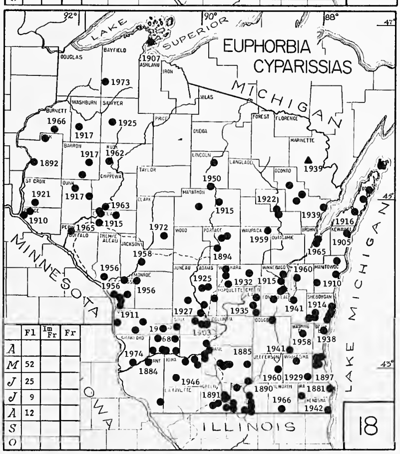
COROLLATA
GLABROUS
Fl | Im Fr | Fr
M 3
J 35 3
J 103 11 3
A 38 47 14
S 3 13 22
15


EUPHORBIA
COROLLATA
● PUBESCENT
○ SLIGHTLY PUBESCENT
Fl | Im Fr | Fr
M 1
J 29 3
J 68 8 1
A 32 27 11
S 1 1 11
16


EUPHORBIA
● PEPLUS
○ COMMUTATA
1965
1933
1934
1960
1889
1884
PEPLUS/COMMUTATA
Fl | Im Fr | Fr
17


EUPHORBIA
CYPARISSIAS
1907
1973
1966
1917
1925
1892
1917
1962
1939
1950
1921
1917
1910
1963
1915
1922
1939
1916
1965
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1972
1905
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1941
1903
1938
1958
1974
1885
1941
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J 25
J 9
A 12
18

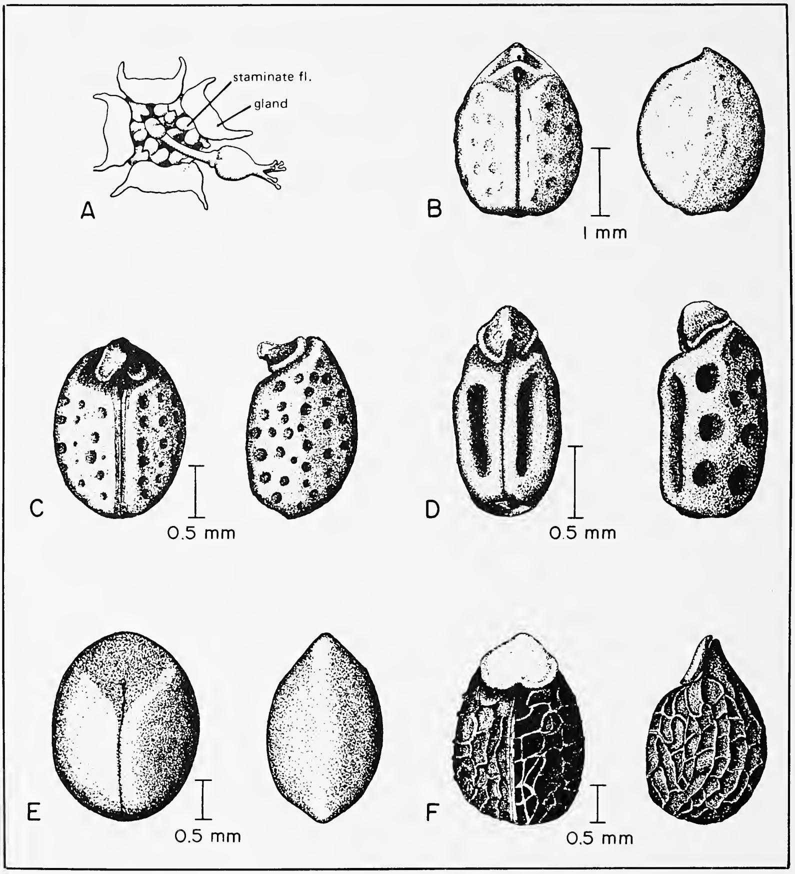


Fig. 8. Seeds and a cyathium of Wisconsin Euphorbias: A) and C) Euphorbia commutata; *B)* E. corollata; *D)* E. peplus; *E)* E. obtusata; *and F)* E. helioscopia. *Cyathium from above; seeds in ventral view (left) and lateral view (right).*

CYATHIA with 5 small yellowish-brown *glands, each with a showy bright-white appendage. CAPSULES* 3–3.8 mm long, *glabrous or nearly so.* SEEDS white to gray, ovoid, 2.1–2.7 mm long, smooth or with shallow depressions arranged in irregular longitudinal rows, ecarunculate.

Widespread in the eastern U.S. and Great Plains on dry to moist, sandy or loamy soils of open woodlands and clearings, prairies, and abandoned fields, in Wisconsin this conspicuous species prevalent in a number of native communities (Curtis 1959), especially in open, sandy or gravelly sunny places, in prairies, thin jack pine or scrub oak woods, barrens and cedar glades, sandstone ridges, limestone bluffs, sand flats, blowouts, and lake shores, commonly weedy in abandoned fields, roadsides, railroads, fencerows, and occasionally quarries or city lots, primarily in the southern two-thirds of the state. As Fassett (1933) indicated, the occurrence of the species in northern Wisconsin presumably results from the plant's having spread along railroads and highways beyond its native range, which possibly reaches as far north as St. Croix, Wood, and Outagamie counties. The overall distribution of the species has barely changed since Fassett's study. Curiously, the earliest Wisconsin specimen seen is from Racine County and was not collected until 1892, although *E. corollata* was listed in a number of early reports, beginning with Lapham (1836). Subsequently, collections became increasingly common, the species being known from Lincoln Co. as early as 1893 and several other northern counties by the 1910's. It was probably spreading rapidly northward soon after the turn of the century. Flowering 27 May to 1 (21) Sep; fruiting 8 Jul to 27 Sep, dispersed as early as (8) 24 Aug.

Several species and/or varieties have been segregated from the extremely variable *E. corollata* complex. These include: var. *corollata,* which is glabrous and has the cyathia on loosely forked inflorescences, pedicels (at the dichotomy) 7–30 mm long, and appendages 7–10 mm broad; var. *paniculata* (Ell.) Boiss., also glabrous, characterized by more crowded cyathia on shorter pedicels (0.5–5 mm long) and relatively small appendages (5–7 mm broad); and var. *mollis* Millsp., distinguished from var. *corollata* by soft pubescence on the stem and on the surfaces of the leaves. Delimiting varieties on such characters as leaf width, peduncle length, pubescence, and appendage width in our area is of no value because variation on an individual plant can, in many cases, incorporate the spectrum of variability. For example, in the most commonly recognized variety, var. *mollis,* there is complete intergradation in Wisconsin between plants possessing stems and leaves with dense, almost woolly pubescence; those with glabrous stems but one or both leaf surfaces glabrous to densely hairy; and others completely glabrous. Gleason (1952) and Steyermark (1963) both state that the presence or absence of pubescence appears to be an environmental response, the more pubescent plants being found in drier exposed situations. Richardson (1968) found no correlation between pubescent forms and drier habitats on the Great Plains, and his studies (unpubl.) did not confirm any demonstrable trends in Wisconsin for increased pubescence on drier sites. Furthermore, glabrous and pubescent forms can usually be found not only in the immediate vicinity of one another, but sometimes also mixed within one population. Where variously pubescent forms were found in a given colony, they were the most abundant (almost 60% of the plants); the remaining 40% were completely glabrous. These percentages appear to hold fairly true for mixed populations across the state.

3. EUPHORBIA COMMUTATA Engelm.
Map 17, Fig. 8.
Wood spurge, tinted spurge

Delicate glabrous perennial HERBS, the stems ascending, 2–4 dm tall, branching throughout their length. LEAVES broadly ovate to obovate or oblanceolate, 2–4.5 cm long, those in the whorl at the base of the umbel somewhat broader, the *floral leaves and bracts* subtending cyathia opposite, broader yet *(slightly broader than long),* broadly triangular-reniform and sometimes connate or enveloping the stem. UMBEL lax, with only 3–4 primary rays but these dichotomously branched; glands of cyathium 4, dark, lunate, extended into slender horns twice as long as the breadth of the body, occasionally deeply toothed. CAPSULES 2.7–2.9 mm long, smooth. *SEEDS* 1.9–2.0 mm long, *deeply and uniformly pitted,* dark gray, with a broad thin caruncle.

Infrequent in the eastern U.S. deciduous forest, extending as far west as Minn. to Tex. along streams and ponds in moist woods, also on wooded hillsides or cliffs on or about calcareous soils, native though very rare in Wisconsin, where known only from Big Hill Park, on the west side of Rock River 3½ miles north of Beloit, Rock County. It has been collected there several times, beginning with T. J. Hale in 1861. The wooded riverine terrace where this population still occurs is on public land and should enjoy protection from future destruction. Flowering May and early June; fruiting 30 May to 6 Jul.

4. Euphorbia peplus L. Map 17, Fig. 8.
Petty spurge

Glabrous annual HERBS; stems erect, 1–3 dm tall, freely branching throughout their length. LEAVES alternate, estipulate, petiolate (petioles up to 8 mm long); blades ovate to obovate, 1–2.5 cm long, larger and subsessile in the whorl at the base of the umbel; *floral leaves and bracts* subtending the cyathia opposite, similar in shape to the cauline leaves *(slightly longer than broad).* CYATHIA in a leafy dichotomously branched umbel; glands of cyathium 4, lunate, greenish-yellow, exappendiculate. CAPSULES 1.9–2.1 mm long, each valve with 2 longitudinal keels. SEEDS oblong, 1.5–1.6 mm long, the *dorsal surface with four rows of large pits, the ventral with two longitudinal furrows,* ash-gray, with a ± inconspicuous conical caruncle.

Native of Eurasia, now a locally established weed across much of N. Am., in Wisconsin collected rarely (only twice since the mid-1930's) in the southeast quarter of the state as an inconspicuous weed of yards, gardens, vacant lots, and waste or cultivated ground. Flowering 28 Jun to 13 Sep; fruiting 8 Jul to 18 Oct.

5. Euphorbia cyparissias L.
Map 18, Fig. 9.
Cypress spurge, graveyard spurge

Glabrous *perennial HERBS from extensively creeping rhizomatous rootstocks;* stems solitary or tufted, erect, 1–4 (7) dm tall, unbranched at the base, often with numerous sterile branches and several axillary rays above. Cauline *LEAVES* alternate to scattered, *very numerous,* narrowly oblong to linear, linear-filiform, or linear-spatulate, *1–3 cm long;* inflorescence leaves and bracts subtending the cyathia opposite, broadly cordate to ovate and often yellow to red or purple in age. UMBEL with (6) 9–18 rays, simple or 1–3 times dichotomously branched. Glands of cyathium 4, lunate, yellow-green, exappendiculate. CAPSULES ca. 3 mm long, rarely produced, glabrous, rugulose and with short round tubercles along either side of the sutures. *SEEDS* (when present) oblong-ovoid, 1.5–2 mm long, brownish-gray to silvery-white, *never mottled,* smooth, with a papilliform caruncle.

Native of Eurasia, widely grown as a ground cover and well established as an escape in the northern states and Canada from Me. to Minn. and Colo., south to Va. and Mo., occasionally adventive in nw. U.S., common throughout most of Wisconsin along roadsides, railroads, banks, fields, clearings, and other neglected areas, often spreading from unkempt lawns, old homesites, and cemeteries. If not controlled, cypress spurge can become a serious weed, forming persistent colonies from extensively creeping and forking rhizomes. Our earliest collections are from 1881 and 1894 in Racine and Portage counties, respectively. Flowering from April through August (inflorescence: 20 Apr to 14 Jun; lateral shoots: 22 Jun to 28 Aug); fruiting, when it occurs, appears to be from June through

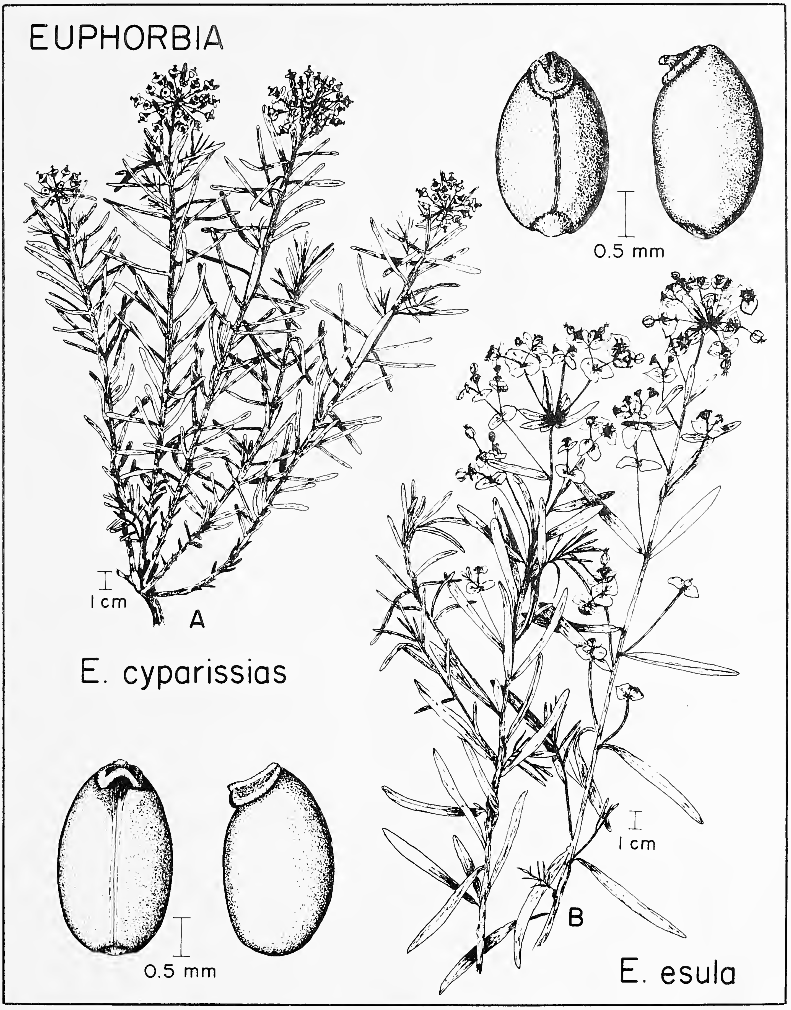


Fig. 9. Habit drawings and seeds (ventral and lateral views) of Wisconsin Euphorbias: A) Euphorbia cyparissias; *B)* E. esula.

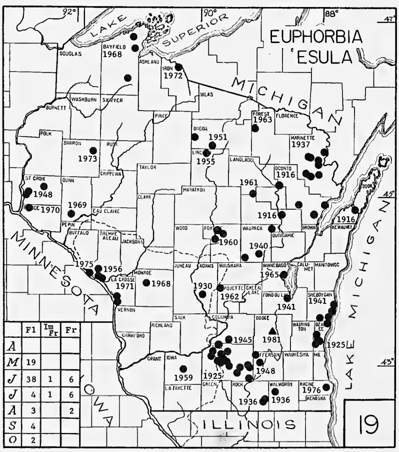
August or September. Fruits are rarely produced, and specimens with viable seeds are even fewer (in examined capsules, two of the three developing chambers were aborted).

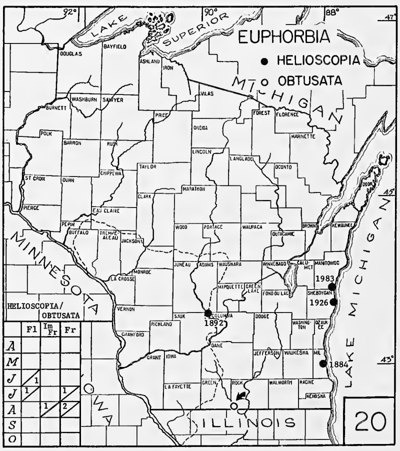
This species is extremely variable but easily recognized, and it is unlikely to be confused with any other except perhaps the sterile, narrow-leaved form of *Euphorbia esula*. Both species produce numerous erect fertile and sterile stems, often forming large colonies. The stems are tufted from a crown and scattered from buds on the rhizomes; but in *E. esula* they are taller and less crowded, and the rootstocks are deeper and more slender. In *E. cyparissias* the very numerous linear leaves are mostly less than 3 cm long and 2.5 mm wide. They are especially dense on the axillary branches, which eventually overtop the inflorescence and give the plant a bushy appearance. *E. esula* has relatively fewer, generally linear-oblanceolate leaves usually more than 3 cm long and 3 mm wide, with the axillary non-flowering branches not overtopping the original inflorescence.

6. Euphorbia esula L. Map 19, Fig. 9.
   Leafy spurge, wolf's-milk
   E. poderae Croiz. of recent annotations

Glabrous *perennial HERBS from horizontal rhizomes and deep roots.* Stems solitary or clustered, erect, 4–9 dm tall, unbranched or sparsely branched near the base, these branches usually sterile; branches below the umbel (axillary rays) usually present and fertile, sometimes numerous, particularly after damage to main shoot. *LEAVES* alternate, *broadly linear to linear-lanceolate or -oblanceolate* or broader in the whorl subtending the umbel, 3–6.5 cm long; floral leaves and bracts subtending the cyathia opposite, shorter and wider than the cauline, broadly cordate. INFLORESCENCE umbelliform, (5-) 7- to 12-rayed, each ray dichotomously branched 1–3 times. Glands of the cyathium 4 (5), lunate, greenish-brown, exappendiculate. CAPSULES 2.5–3 mm long, exserted as much as 1 cm beyond the involucre, somewhat granular-roughened on the keels. SEEDS oblong-ellipsoid, 2–2.3 mm long; *coat smooth,* orangish-brown or silver-gray to white, *typically mottled,* with a dark vertical line (raphe) extending along one side and a conspicuous flattened caruncle.

An aggressive and noxious weed, native of Eurasia, now widely established in N. Am. from Que. and N. Engl. to B.C., south to Md. and Colo., in Wisconsin a fairly recent adventive now widely





naturalized and in many areas a troublesome weed in fields, roadsides, railroads, and other disturbed ground, and an active invader of open oak woods and undisturbed prairie remnants where its extermination presents a hard-to-solve problem. It was first collected in 1916 in Oconto County by Goessl (*s.n.,* WIS). According to Fassett (1933), it was first seen at Madison in 1929, with the earliest collections from 1925 (Dane and Ozaukee cos.), 1928 (Oconto Co.), and 1930 (Adams Co.). A newspaper article from the *Delavan Republican* of July 1, 1937, noted the occurrence of *E. esula* in Wisconsin "in small patches" and stated that it was spreading rather rapidly. The roots are deep, strong, and spread vigorously (they have been traced to a depth of 15 ft. [Bakke, 1936]), making leafy spurge difficult to eradicate. Patches spread vegetatively 1 to 3 ft. per year and produce more than 200 shoots per m^2 in light soils and up to 1,000 shoots per m^2 in heavy soils (see Selleck, 1959). Flowering primarily 11 May to 2 Jul, with some flowering as late as 15 Oct; fruiting 13 Jun through October, with dispersed fruit as early as 4 Sep.

Over the past 70 years authors have held widely different opinions concerning the correct identity of the leafy spurges. Croizat (1945) claimed that the North American populations included in the "esula complex" comprise four taxa, the great majority of plants being hybrids between *E. esula* and *E. virgata* Waldst. & Kit. (*E.* X*intercedens* Podp. [1922] [non *E.* X*intercedens* Pax (1905)], *E.* X*podperae* Croiz. [1947], as well as earlier names). Both *E. virgata* and *E.* X*podperae* are closely related to, if not conspecific with, *E. esula,* and modern students of the American and European floras prefer for now to treat the entire assemblage as one species, *E. esula* L. (1753). However, natural hybrids between *E. esula* (including *E. virgata*) and *E. cyparissias* have been reported (as *E.* X*pseudo-esula* Schur) from Ontario (Moore & Frankton, 1969), and in the treatment of the genus *Euphorbia* for the Great Plains (McGregor, 1986), two distinct entities are given taxonomic recognition, *E. esula* and a presumed hybrid between *E. esula* and *E. virgata* under the epithet *E.* X*pseudovirgata* (Schur) Soo. This hybrid consistently produces cauline leaves that are only 3–5 mm wide, widest at or below the middle, and tapering toward the apex, whereas the true *E. esula* has the main stem leaves 3–10 mm wide, widest above the middle, and rounded at the apex. No segregation of Wisconsin material has been attempted on these bases.

See notes under E. *cyparissias* (no. 5).

7. Euphorbia obtusata Pursh
Blunt-leaved spurge   Map 20, Fig. 8.

Glabrous annual HERBS; stems erect, 3–7 dm tall, unbranched for most of their length. LEAVES alternate, estipulate, sessile, the *blades oblanceolate to oblong-oblanceolate or slightly pandurate,* serrulate, the upper ones subcordate and somewhat clasping at the base, those subtending the umbel similar but broader, the floral leaves and bracts subtending the cyathia broadly ovate. Primary rays of UMBEL 3 (rarely 5), sometimes branching more than once; *cyathium with* 4 or 5 *exappendiculate red or reddish- or orangish-brown* transversely elliptic *glands. CAPSULES* 2.7–3.2 mm long, *verrucose. SEEDS lenticular,* 2–2.1 mm long, dark grayish-brown, *with a smooth or obscurely reticulate surface and a papilliform caruncle.*

Occasional in the southeastern U.S. from S.C. to e. Tex., north to Pa., se. Mich. (where probably adventive), and Ia., in more or less damp rich woods (often on wooded banks of rivers and ponds), alluvial fields, and roadsides, the only Wisconsin collection from "Nelson Rd Sugar River bottom" in Rock County

(*Fell 57-404,* 10 Jun 1957 [fl], WIS). If assumed to be native rather than adventive from farther south, it is at the northern edge of the range of the species. It has been reported from along the Pecatonica and Sugar rivers in adjacent Winnebago County, Illinois (Fell, 1955). Flowering May and June; fruiting primarily in July.

8. EUPHORBIA HELIOSCOPIA L.
Map 20, Fig. 8.
Wartweed, sun spurge

Glabrous annual HERBS, the single main stem ascending, 2–5 dm tall, scarcely branched. LEAVES alternate, sessile, soon falling, 1.5–4 cm long, scale-like below, spatulate to oblong-obovate higher on the stem and obovate to broadly elliptic in the whorl below the umbel; floral leaves and bracts subtending th cyathia similar to those in the whorl, shorter but broader and often yellowish; all *leaves finely serrate,* especially at the very rounded apex. Primary *UMBEL* usually *with 5 short rays,* each forked into 3 divisions or becoming repeatedly branched on plants from rich-soil sites; *cyathia with 4 suborbicular or elliptic, brownish- or yellowish-green exappendiculate glands. CAPSULES* 2.6–3.1 mm long, *smooth. SEEDS ovoid-subglobose,* 2–2.2 mm long, *reticulate-rugose,* brown; caruncle conspicuous.

A native of Europe, widely naturalized from e. Can. to Man., south to N.Y. and Mich., and locally adventive farther south to Md. and Ill., in Wisconsin once sparingly established as an escape or adventive at the Dells of the Wisconsin River, county not specified (*Monroe 9709,* 5 Aug 1892 [fr], MIL); Milwaukee (*Hasse 744,* Jul 1884 [fl], MIL); and Sheboygan (*Goessl s.n.,* Jul 1912 [fr], WIS; *Davis s.n.,* 25 Aug 1926 [fr], WIS), now occasionally planted as an ornamental and sometimes escaped to adjacent fields and waste areas or persisting in recently abandoned gardens. No habitat information is associated with Wisconsin specimens except for the only recent one: Manitowoc Co.: Cleveland, green bean field (transmitted by *Doll s.n.,* ± 26 Aug 1983 [fr], WIS).

Acknowledgments

Figure 1 and cyathia in Figures 4 and 5 are from *A Student's Atlas of Flowering Plants: Some Dicotyledons of Eastern North America,* by Carroll E. Wood, Jr., and are copyrighted (© 1974) by Harvard University. They are reproduced by permission of Harper & Row, Publishers, Inc. Research was supported in part by UW Institutional Research Grant #0380-9-75 to J.W.R. The manuscript was read by Dr. Hugh H. Iltis, to whom we extend our thanks.

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Volume 76
1988

Transactions

Carl N. Haywood, Editor
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TRANSACTIONS

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of Sciences, Arts and Letters

Volume 76 • 1988

Contents

Use of Discriminant Analysis to Classify Site Units Based on Soil Properties and Ground Vegetation 127

James R. Trobaugh and James E. Johnson

Classification of forest land into distinct units is an important area of research in the United States. In this paper Professors Trobaugh and Johnson determine 1) the variation among soil properties and ground vegetation within site units and 2) the importance of these variables in discriminating among three common site classification units in northeastern Wisconsin.

Addendum

In the 1987 Volume of *Transactions* the publication of the article entitled "The Flora of Wisconsin, Preliminary Report No. 69. Euphorbiaceae—The Spurge Family" by James W. Richardson, Derek Burch, and Theodore S. Cochrane was aided by the Norman C. Fassett Memorial Fund.

From the Editor

In Volume 75 (1987) of *Transactions,* I indicated my intention that the journal will continue to reflect the diverse interests and activities of the members of the Wisconsin Academy as well as serve as a place where original work by Wisconsin writers or about Wisconsin will be published. Articles for Volume 76 (1988) were selected with this intent, and it is hoped that the readers will enjoy both the diversity and quality. Each article has undergone careful review by outside readers as well as by a number of staff members. Rigorous professional review and editing are part of the process articles undergo prior to being presented to the readers of *Transactions.* This procedure has resulted in what I think is an outstanding issue.

Two aspects of this volume are new. Readers will remember the poem presented in the 1987 edition; in the current issue there are additional poems that represent the high quality of the work of Wisconsin poets. In addition to the poetry, there is a series of photographs by David Ford Hansen, one of Wisconsin's most talented photographers. One will quickly recognize the technical skill and the universal human emotion captured in both the poetry and the photographs. Though no definitive decision has been made, it is my hope that *Transactions* will continue to include a poetry section and photographs or a photographic essay in future volumes. Anyone wishing to submit material for the latter should contact the editor.

Two articles in this volume will be of particular interest to many readers. In 1977 The Wisconsin Department of Natural Resources (DNR) designated a group of lakes as "benchmarks." The purpose of this was to collect data in order to monitor long-term limnological conditions and changes in lakes minimally affected by human activities. The result should provide benchmarks against which to measure changes. *Transactions* is pleased to publish Professor Nichols' study of "Vegetation of Wisconsin's Benchmark Lakes" in which he describes the macrophyte vegetation found in the fourteen lakes. A second paper that will draw immediate note presents a new interpretation of the bitter strike at the Allis-Chalmers plant in West Allis, Wisconsin, in 1946–1947. Julian Stockley has reexamined the data and argues for a new interpretation of an event that still raises great emotions in many Wisconsin circles.

We at *Transactions* are pleased to present this volume of the journal to our readers. Any comment, suggestion, or submission should be addressed to the Editor.

Carl N. Haywood

Vegetation of Wisconsin's Benchmark Lakes

Stanley A. Nichols

Abstract. *This paper describes the macrophyte vegetation found in 14 benchmark Wisconsin lakes. This information forms a base to study long-term changes in the plant community when compared to future sampling efforts. A variety of limnological parameters were compared to vegetational characteristics of the benchmark lakes. Correlations between pH, alkalinity, specific conductance, free CO_2, substrate type, and acres less than 6 m and the community attributes of maximum depth of plant growth, open area in the littoral zone, diversity, and littoral zone development were tested singly and with multiple regression analysis. Not surprisingly no significant linear correlations were found. Different factors are probably responsible for determining each plant community; the dominant species in these communities often have unique adaptations to cope with environmental limitations.*

In 1977 The Wisconsin Department of Natural Resources (DNR) selected a group of lakes as benchmark lakes. The objective of the benchmark lakes program is to monitor basic limnological conditions and long-term limnological changes in lakes that are minimally affected by human activities. Changes occurring in these lakes are primarily due to natural causes, and it is assumed that changes will be much slower than in lakes that are influenced by human activities.

Besides their undisturbed nature, primary selection criteria included some assurance that neither the lake nor the associated watershed undergo significant manipulation in the future. The lakes were geographically distributed and screened for limnological characteristics so that a spectrum of lake types were represented (Fig. 1). These lakes were selected by DNR personnel; no effort was made to select the lakes randomly. Where human influence on lakes is historically significant, such as in southeastern Wisconsin, efforts were made to select the best available lakes to represent the lake types of the region.

Macrophyte sampling occurred in the lakes between 1978 and 1981. This paper reports aquatic vegetation found in the lakes during the first sampling effort. This information forms a base to study long-term community changes.

A variety of authors (Pearsall 1920;

Fig. 1. Location of benchmark lakes.

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Spence 1972; Seddon 1972; Moyle 1945; Lind 1976; Olsen 1950; Swindale and Curtis 1957; Barko et al. 1986) found that pH, alkalinity, free CO_2, conductivity, and sediment type influenced the character of aquatic plant communities. These limnological parameters were compared to vegetational characteristics of the benchmark lakes. The objective was to better define the relationship between the aquatic environment and the aquatic vegetation, especially in light of recent information regarding the relationship of carbon to the form, function, and physiology of aquatic plants (Adams 1985).

Methods and Analysis

Depending on the importance of macrophytes in the lake, the macrophyte community was sampled annually for from one to four years. Sampling was conducted by DNR field staff of the district in which the lake occurred. This sampling generally took place during late July or August. The macrophyte sampling technique used was that of Jessen and Lound (1962). To assure geographic coverage of the lake, sampling points were selected by overlaying a grid on a lake map. Grid size and the number of sampling points per lake varied depending on the size of the lake.

At every sampling point, water depth was measured and the substrate was categorized as being hard (sand or gravel) or soft (silt, muck, or flocculent). All plant species within a 2-m diameter circle around the sample point were recorded, and a qualitative density rating was assigned to each species on the basis of the criterion established by Jessen and Lound (1962). Species unknown by the field staff were collected and sent to the Wisconsin Geological and Natural History Survey for identification or verification. They were then sent to the University of Wisconsin Herbarium as voucher specimens.

From this data a variety of floral and vegetational characteristics of the lakes was established (Table 1). The maximum depth of plant growth is the depth of the deepest sampling point where vegetation was found during all sampling periods. The open area in the littoral zone was calculated as the frequency of occurrence of sampling points with no vegetation that were found in water depths equal to or more shallow than the maximum depth of plant growth.

A species was included in the flora of a lake and thus contributed to the total taxa found in the lake if it occurred in the lake during any sampling period. The frequency of occurrence of a species was calculated as the number of occurrences of a species divided by the total number of sampling points with vegetation. Likewise average density was calculated as the sum of the density ratings for the species divided by the total number of sampling points with vegetation. The frequencies were relativized and an importance value (IV) was calculated by multiplying the relative frequency by the average density. The importance value of a species is reported if it was at least 5 in at least one lake.

The sum of the IV of a lake could vary from zero in a lake with no plants to 500 in a lake where 100% of the plants have an average density of 5. Littoral zone development was calculated by multiplying the sum of the IV by one minus the percentage of open area in the littoral zone (i.e., sum of IV [1 – percent of open area in littoral zone]). Again, this value could vary from 0 to 500. It gives a general indication of the robustness and distribution of the macrophyte community.

Diversity was calculated using the formula one minus the sum of the relative frequencies squared of the species in a lake [i.e., 1 – sum of (relative frequencies)^2]. This is a modification of Simpson's (1949) diversity index.

The mean dissimilarity per year was calculated using the dissimilarity index $1-2w/a+b$ (Bray and Curtis 1957) on species IV for each sampling period. These dissimilarities were then averaged for all sampling periods for each lake.

The values for alkalinity, pH, specific conductance, secchi disk reading, and area less than 6 m deep were obtained from DNR files. Free CO_2 was calculated using the nomogram technique found in Standard Methods (AHPA 1971) and assuming a standard temperature of 20°C and total dissolved solids equal to 0.65 times the specific conductance. The percentage of hard bottom was the frequency of sampling points with vegetation having a sand or gravel substrate. Physical and community characteristics of the lakes are presented in Table 1. Two multivariate techniques were used to display the similarities and differences of lakes based on physical factors: a Bray and Curtis (1957) ordination using a dissimilarity index of $1-2w/a+b$ and a cluster analysis using the number cruncher statistical system (Hintze 1986). The physical factors used were pH, alkalinity, conductivity, free CO_2, and percent hard bottom.

The lakes in Tables 1–3 (see end of article) are organized by the group they formed in the above ordination. Group I lakes are listed at the top or left side of a table. These lakes have low alkalinity, low pH, and low specific conductance. Group V lakes are on the right side or bottom of the tables. They are lakes with high alkalinity, high pH, and high specific conductance.

Results

Flora

Table 2 displays plant species identified for the lakes. In total 95 taxa were identified. The species richness varied from 10 species in Ennis Lake to 35 species in Anodanta and Allequash Lakes. Average species richness is 20 species per lake.

By examining the columns of Table 2, one can observe in which group or groups of lakes a species was found. Allequash and Anodanta were the two most species-rich lakes. Each lake contained 35 species. Both lakes are near neutral pH, have a moderate alkalinity and light penetration, and have a predominantly soft bottom. In addition, Allequash Lake has a large area less than 6 m deep. However, no significant linear correlation was found between species richness and specific conductance, pH, alkalinity, free CO_2, secchi disk reading, percent of quads with a hard bottom, or bottom area less than 6 m deep for the benchmark lakes.

Chara spp., *Dulichium arundinaceum, Eleocharis* spp., *Elodea canadensis, Najas flexilis, Nuphar variegatum, Potamogeton amplifolius* and *Vallisneria americana* were the taxa most frequently found. All the above mentioned species were found in 50% or more of the lakes (Table 2). All the submerged species in this group are dominant members of the plant community in one or more lakes (Table 3).

Myriophyllum spicatum and *Potamogeton crispus,* two foreign invasive species, were collected in the benchmark lakes. *M. spicatum* was found in Town Line and Devils Lakes. The author also collected *M. spicatum* from Pine Lake in Waukesha County during the summers of 1984 and 1985. Ottawa Lake was the sole location for *P. crispus.* All these lakes, except Town Line, are in southern Wisconsin where lake use is much more intense.

Community attributes and correlation with environmental factors

Correlations between alkalinity, pH, specific conductance, free CO_2, percent hard bottom, and acres less than 6 m deep and the community attributes of maximum depth of growth, open area in the littoral zone, diversity, and littoral zone development were tested singly and with multiple regression analysis. No significant linear correlations were found. It is especially surprising that there was no correlation between secchi disk reading and maximum depth of growth.

Species diversity between lakes is difficult to compare. The vegetation parameters for calculating diversity were not based on equal sampling areas. Thus, larger lakes could have a higher diversity because of the larger area sampled. This may be the case for Allequash Lake. However, Prong, Perch, Town Line, and Anodanta Lakes have a high diversity but a small littoral zone.

The above calculations only indicate that there was no significant linear correlation found between the environmental and vegetational parameters studied. The environmental influence on the vegetation and community attributes based on ordination analysis is presented later in the paper.

Community change

For all lakes except Allequash, Clear, and perhaps Moon, Ennis, and Devils, the aquatic plant communities are very stable. Cox (1969) indicates that replicate samples of the same community usually show a coefficient of similarity of 0.85 (i.e., a dissimilarity of 0.15). All lakes except those mentioned above have dissimilarity values near 0.15. Therefore, the plant communities changed very little during the years they were studied.

The difference in Clear Lake from August 1979 to August 1980 is due to a dramatic increase in *Isoetes* sp. and *Najas flexilis.* They increased in importance from 6.8 to 26.1 and 0.1 to 11.2, respectively. Both species nearly doubled the frequency of quadrats in which they were found and their average density rating.

Allequash Lake experienced a decrease in the importance of *Ceratophyllum demersum* and *Elodea canadensis* between August 1979 and August 1980. They decreased in importance from 50.5 to 17.7 and 13.6 to 4.8 respectively. The decrease was due primarily to a drop in density of growth rather than in a change in frequency.

In Moon Lake there was a decrease in growth and distribution of *Chara* sp. between late July 1979 and early August 1981. This was accompanied by an increase in growth and distribution of *Vallisneria americana.* The importance value of *Chara* sp. dropped from 34.4 to 12 and that of *V. americana* increased from 43 to 110.7 during this time period.

In Devils Lake there was a trend of gradually decreasing *Myriophyllum spicatum* importance from August 1978 to August 1981. Importance decreased from 84 to 32 during this time period. A dramatic increase in *Elodea canadensis* from 19 in August 1980 to 105 in August 1981 also occurred. This trend has changed more recently. Lillie (1986) found *Potamogeton robbinsii* to be the most important species in Devils Lake, and *M. spicatum* became more important at the expense of *E. canadensis.*

Chara sp., *Potamogeton praelongus* and *Najas flexilis* shifted in importance in Ennis Lake between August 1978 and August 1981, but no trend was apparent.

Lake communities

Table 3 displays the frequency, relative frequency, average density, and importance value of the common species in each lake. A species was retained if it had an importance value of 5 or more in any lake within its group.

By imposing an importance value criterion of 5 on the species, the number of taxa was reduced from 95 to 28. In other words, only about 29% of the taxa recorded for the lakes were very important in one or more lakes.

Vegetational relationships to ordination and clustering of physical characters

The lakes with similar environmental

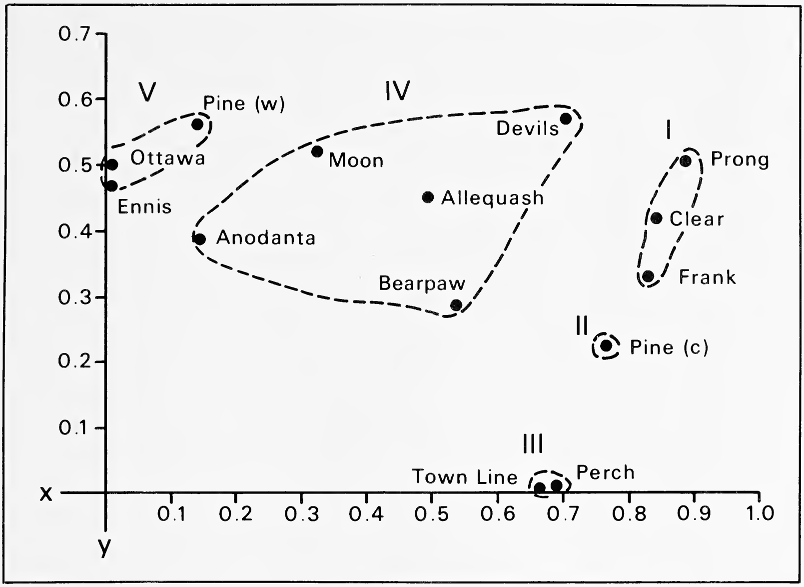

Fig. 2. Ordination of benchmark lakes based on environmental attributes.

attributes were grouped using ordination and clustering techniques. The ordination of lakes is displayed in Figure 2. The lake groups displayed in Figure 2 were determined by inspection and are therefore subjective. The groups formed display a distinct flora, vegetation, and littoral zone development. Each group has a unique assemblage of important species, the littoral zone development between the groups varies tremendously, and the highest commonality of the flora between groups is 58% (Tables 3, 4 and 5).

Cluster analysis gave slightly different results. To form five groups, clustering lumped Pine(w), Ottawa, and Ennis; Town Line and Perch; and Prong, Clear, and Frank. To this extent, clustering gave similar results as ordination. Clustering added Devils to the Prong-Clear-Frank Lake group and Pine(c) to the Perch-Town Line group, and separated Allequash-Bearpaw Lakes and Moon-Anodanta Lakes. Although the determination of groups using clustering may be more mathematically rigorous, the selection of the final number of groups is subjective, so it is probably no better or worse than the inspection technique.

The groups formed by ordination and inspection were selected as a basis for discussion in this paper. The comparison of the two methods indicates that describing plant communities found at the extremes of environmental conditions will likely be easier than describing those found in moderate conditions. For instance, Devils Lake has a floral similarity of 0.21 with Group I lakes and 0.22 with the remaining Group IV lakes. On the basis of flora, it could logically be combined with Group I, Group IV, or considered intermediate. The case for placing Pine(c) lake in Group III versus Group I

Table 4. Summary of vegetation attributes

	Group I	Group II	Group III	Group IV	Group V
Average maximum growth depth (m)	4.6	5.0	4.6	4.0	4.7
Average diversity	0.86	0.76	0.87	0.86	0.74
Average no. taxa	21	21	20	22	14
Average lit. zone development	15	16	98	47	114

on the basis of floral similarity is better (coefficient of floral similarity is 0.46 vs. 0.36), but not overwhelmingly so. A much larger data base is needed to better define plant communities in moderate environmental conditions.

Discussion and Conclusions

The benchmark lakes are only a small percentage of Wisconsin's 14,000 lakes and the taxa represented constitute less than half of the potential plants in Wisconsin's lakes (R. Read, Wisconsin DNR, personal communication). Therefore, the sampling is not necessarily representative of the variety of Wisconsin lakes and lake plants. However, interesting relationships between aquatic vegetation and habitat factors emerge even in this small group of lakes.

Group I. Lakes in Group I have low pH, alkalinity, and specific conductance, which lead to low free CO_2 and low total dissolved inorganic carbon. Low carbon availability may be the key factor explaining the vegetation and productivity of these lakes. The plant community is strongly dominated by floating leaved species such as *Brasenia schreberi* and rosette plants such as *Isoettes* spp. The stomata of *B. schreberi* occur on the upper epidermis of the floating leaf (Sculthorpe 1967). This is a useful adaptation in a carbon limited environment because atmospheric CO_2 can be utilized for photosynthesis. In other words, as Steeman-Nielsen (1944) points out, aquatic plants that have organs of assimilation above the surface of the water are not photosynthetically aquatic plants.

Some rosette plants, especially the Isoetids, can maximize the utilization of CO_2 through such mechanisms as crassulacean acid metabolism, the use of sedimentary dissolved inorganic carbon, a leaf morphometry that lowers the boundary layer resistance to CO_2 flux across the unstirred layer of water next to the leaf, and recycling of respired CO_2 (Adams 1985).

Group II. Pine Lake in Chippewa County is the lone lake in Group II. The vegetation of Pine Lake is clearly distinct from Group I or Group III lakes (Tables 4 and 5) *Potamogeton epihydrus* is the only submerged species that Groups I and II have in common. Pine Lake is not florally depauperate. However, the majority of the species are emergent or floating leaved species, including *Nymphaea tuberosa,* the only important species in the lake. Even the submerged species *Potamogeton natans, Potamogeton gramineus,* and *Potamogeton epihydrus* can have floating leaves. Again, these species have their organs of assimilation out of the water so they are not totally dependent on the water to obtain their resources. However, water depth limits the potential habitat they can occupy.

No submerged species are important in this lake. More recent water chemistry data indicate a higher pH and lower alkalinities than those reported in Table 1 (pH 6.6–7.0, total alkalinity 6.0–8.0). These data would slightly shift the location of Pine Lake in the ordination; however, they better explain the vegetation pattern. There is no development of acidophilous flora (Wetzel 1984) and free CO_2 would be much more limited.

Group III. The vegetation in the Group III lakes is typical of a bog lake. The alkalinity, specific conductance, and pH of the lakes are low but the littoral zone development is high. The primary habitat difference between Group III lakes and Group I and II lakes appears to be that Group III lake bottoms consist primarily of soft sediments.

The adaptation of the floating leaves of *B. schreberi* and *N. odorata* for living in a carbon-poor environment has been discussed previously. The genus *Utricularia* also has some interesting adaptations. Many members of this genus are submerged and free floating. They have a large surface area because of their finely dissected leaves, which allows them to absorb nutrients over their whole surface. This may give them an advantage in obtaining nutrients and carbon from a nutrient-poor environment or obtaining nutrients and carbon from rich organic sediments (Wetzel et al. 1985). Many *Utricularia* are carnivorous. Aquatic animals caught in the traps of these carnivores are probably a significant source of phosphorus, nitrogen, and perhaps some minor elements (Hutchinson 1975).

Group IV. The mesic lakes are contained in Group IV. Alkalinities are higher in Group IV lakes than they are in Groups I, II, or III lakes. Therefore, dissolved inorganic carbon conditions are more favorable for the growth of submerged species. All the important species except *Nuphar advena* are submerged species. Species in this group, such as *Elodea canadensis* and *Myriophyllum spicatum,* have the ability to use bicarbonate as a carbon source for photosynthesis (Nichols and Shaw 1986). This is an advantage in lakes where alkalinities are moderate to high, but where high pH limits the free CO_2. Group IV represents a large and diverse group of lakes. As mentioned previously, subgroups could probably be defined with a larger sampling of this lake group.

Table 5. Floral similarity of lake groups

	I	*II*	*III*	*IV*	*V*
I	1.00				
II	0.36	1.00			
III	0.40	0.46	1.00		
IV	0.51	0.34	0.58	1.00	
V	0.35	0.28	0.34	0.42	1.00
Mean Similarity	0.41	0.36	0.45	0.46	0.35

Group V. The hard-water lakes of Group V typically have a high alkalinity, high pH, and high specific conductance. They also are low in free CO_2. Species that are predominant in these lakes need bicarbonate to photosynthesize effectively. The data indicate that *Chara* is the most successful species under these conditions. Little was found in the literature about the ability of *Chara* to use bicarbonate. Wetzel (1960) suggests the large surface area of *Chara* aids carbon uptake and that some algal species can utilize bicarbonate ion faster than higher plants because the chloroplasts are much closer to the carbon source. Carbon need not be transported as far as is the case with vascular hydrophytes, so there is less resistance to carbon flux from the environment to the chloroplast. These two factors could explain the dominance of *Chara* under the conditions found in Group V lakes. However, Maberly and

Spence (1983) rated *Chara* sp. much lower in its ability to extract inorganic carbon from the water than *M. spicatum,* and somewhat similar in ability to *P. crispus* and *E. canadensis.*

Chara is interesting because it is a widespread species, but becomes dominant only in the hard-water lakes. In other lakes *Chara* and *Najas flexilis* act as early successional species and are readily replaced by other macrophytes (Nichols 1984; Engel and Nichols 1984). This does not appear to be the case in Group V lakes.

Wetzel (1966) states that low productivity is characteristic of this lake type. This is not inconsistent with the fact that these lakes have the highest littoral zone development. Littoral zone development refers more to the area the plants occupy rather than their productivity. *Chara* spp. and *Najas flexilis* are often small in stature and do not produce a lot of structural material. They can occupy a large area without being productive.

It is interesting to note that *Najas flexilis, Ceratophyllum demersum, Elodea canadensis, Myriophyllum spicatum* and *Vallisneria americana* displayed dramatic population shifts in the lakes during the course of the study. These species often cause aquatic nuisance problems in lakes (Trudeau 1982). These data indicate that these species are naturally dynamic and can therefore rapidly take advantage of plant population shifts in a lake. In a lake where a perturbation occurs, these species may readily be able to take advantage of the situation and become dominant.

In summary, this study supports the observations of other authors cited in the introduction that pH, alkalinity, specific conductance, free CO_2, and substrate type are important in determining the plant community and plant distributions in lakes. It is not surprising that there is a lack of linear correlations between these factors and vegetational characteristics. Different factors are probably responsible for determining each plant community, and the dominant species in these communities often have unique adaptations to cope with environmental limitations.

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Table 1. Physical and community characteristics of the benchmark lakes.

Lake	County	Total alkalinity mg/1 $CaCO_3$	pH	Specific conductance umhos /cm 25°C	Free CO_2 mg/1	Hard bottom (%)	Secchi (m)	Acres <6 m	Total Taxa	Maximum depth growth (m)	Open litt (%)	Diversity	Littoral zone development	Mean dissimilarity /year
Prong	Vilas	5	6.6	20	2.4	83	4.5	16	24	5.1	68%	0.90	20	0.18
Frank	Vilas	10	7.1	29	1.5	54	3.1	127	14	5.1	68%	0.86	7	ND*
Clear	Oneida	10	6.8	27	3.0	73	5.9	94	26	3.6	35%	0.81	17	0.70
Pine(c)	Chippewa	17	5.8	26	32.0	42	4.6	66	21	5.0	69%	0.76	16	0.20
Perch	Bayfield	8	6.0	28	15.0	9	3.1	39	19	5.1	14%	0.86	107	0.16
Town Line	Chippewa	9	6.0	35	16.0	6	1.3	41	20	4.0	37%	0.88	88	0.14
Bearpaw	Oconto	21	6.8	71	6.5	7	3.1	149	15	3.0	65%	0.80	30	0.17
Devils	Sauk	21	7.2	85	2.6	87	5.2	94	12	3.6	35%	0.81	79	0.23
Allequash	Vilas	39	7.8	87	1.4	21	3.1	320	35	4.8	63%	0.92	26	0.47
Moon	Marinette	79	6.8	200	22.0	48	4.4	82	13	4.8	46%	0.82	52	0.27
Anodanta	Bayfield	90	6.8	238	26.0	9	2.5	22	35	3.9	42%	0.94	47	0.16
Pine(w)	Waukesha	139	8.5	360	0.8	45	3.3	141	11	5.4	41%	0.65	97	0.17
Ennis	Marquette	201	8.2	339	2.2	2	1.7	21	10	3.6	13%	0.80	112	0.23
Ottawa	Waukesha	265	7.8	471	6.2	17	2.3	28	20	5.1	23%	0.78	132	0.15

* No Data

Table 2. Flora of the benchmark lakes.

	Prong	Frank	Clear	Pine (c)	Perch	Town Line	Bear-paw	Devils	Alle-quash	Moon	Ano-danta	Pine (w)	Ennis	Ot-tawa	Occurrence (%)
Brasenia schreberi	1	0	0	1	1	1	0	0	1	0	0	0	0	0	36
Calla palustris	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Carex spp.	1	1	1	0	0	0	1	0	0	0	0	0	0	1	36
Ceratophyllum demersum	0	0	0	0	1	0	0	1	1	0	1	1	0	0	36
Ceratophyllum echinatum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	7
Chara spp.	1	1	1	0	0	0	0	1	1	1	1	1	1	1	71
Dulichium arundinaceum	1	1	1	1	1	1	1	0	0	0	0	0	0	0	50
Elatine minima	1	0	1	0	0	0	0	0	0	0	0	0	0	0	14
Elatine sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7
Eleocharis acicularis	1	0	1	1	1	0	0	0	0	0	0	0	0	0	29
Eleocharis palustris	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7
Eleocharis spp.	0	0	1	1	0	1	1	0	1	0	1	0	0	1	50
Elodea canadensis	0	0	1	0	0	0	1	1	1	1	1	0	1	0	50
Equisetum fluviatile	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7
Eriocaulon septangulare	1	0	1	0	1	0	1	0	0	0	1	0	0	0	36
Glyceria canadensis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7
Glyceria spp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	14
Gratiola aurea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Heteranthera dubia	0	0	0	0	0	0	0	0	1	1	1	0	0	0	21
Iris versicolor	0	1	0	1	0	0	0	0	0	0	0	0	0	0	14
Isoetes echinospora	0	1	0	0	1	0	0	1	0	0	0	0	0	0	21
Isoetes macrospora	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Isoetes spp.	0	0	1	0	0	0	0	0	1	0	0	0	0	0	14
Juncus spp.	0	0	1	1	1	0	1	0	0	1	0	0	0	0	36
Lemna minor	0	0	0	0	1	0	0	0	1	0	1	0	0	0	21
Lemna trisulca	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7
Lobelia dortmanna	1	0	1	0	0	0	0	0	0	0	0	0	0	0	14
Megalodonta beckii	0	0	0	0	0	0	0	0	1	0	1	0	0	0	14
Myriophyllum exalbescens	0	0	1	0	0	0	0	0	1	0	0	0	0	0	14
Myriophyllum farwellii	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7
Myriophyllum spicatum	0	0	0	0	0	1	0	1	0	0	0	0	0	0	14
Myriophyllum tenellum	1	0	1	0	0	0	0	0	0	0	0	0	0	0	14
Myriophyllum verticillatum	0	0	0	0	0	0	0	0	0	0	1	0	1	0	14

Table 2. Flora of the benchmark lakes.—Continued

	Prong	Frank	Clear	Pine (c)	Perch	Town Line	Bear-paw	Devils	Alle-quash	Moon	Ano-danta	Pine (w)	Ennis	Ot-tawa	Occurrence (%)
Myriophyllum spp.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	14
Najas flexilis	0	1	1	0	0	0	1	0	1	1	0	0	1	1	57
Najas gracillima	0	0	1	0	0	0	0	0	0	0	1	0	0	0	7
Najas guadalupensis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	7
Najas marina	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Najas sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7
Nitella spp.	0	1	1	0	0	1	0	1	0	0	1	0	0	1	43
Nuphar advena	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7
Nuphar variegatum	0	1	1	1	0	1	0	0	1	0	0	1	1	1	57
Nuphar spp.	0	0	0	0	1	0	0	0	1	0	1	0	0	1	29
Nymphaea odorata	1	1	0	1	0	1	0	0	1	0	0	1	0	0	43
Nymphaea tuberosa	1	0	0	0	0	0	1	0	0	0	1	0	0	0	21
Nymphaea sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7
Polygonum amphibium	1	0	0	0	0	1	0	0	0	0	0	0	0	0	14
Pontederia cordata	0	1	0	1	0	0	0	0	0	0	1	0	0	0	21
Potamogeton amplifolius	0	0	1	0	0	1	1	1	1	1	1	1	1	1	71
Potamogeton crispus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Potamogeton diversifolius	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Potamogeton epihydrus	1	0	0	1	1	1	0	0	0	0	1	0	0	0	36
Potamogeton gramineus	0	0	0	1	0	1	1	1	1	1	0	0	0	0	43
Potamogeton illinoensis	0	0	0	0	0	0	0	1	0	0	0	1	0	1	21
Potamogeton natans	0	0	0	1	0	1	1	0	0	0	1	0	1	0	36
Potamogeton nodosus	1	0	0	0	0	0	0	0	0	0	0	1	0	0	14
Potamogeton oakesianus	0	0	0	0	1	0	0	0	1	0	0	0	0	0	14
Potamogeton obtusifolius	0	0	0	0	0	0	0	0	1	0	1	0	0	0	14
Potamogeton pectinatus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	14
Potamogeton praelongus	0	0	0	0	0	0	0	1	1	0	1	0	1	0	29
Potamogeton pusillus	0	0	1	0	0	1	0	0	0	1	1	0	0	0	29
Potamogeton richardsonii	0	0	0	0	0	0	0	0	1	1	1	0	0	0	21
Potamogeton robbinsii	1	0	0	0	0	0	0	1	1	1	1	0	0	0	36
Potamogeton spirillus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7
Potamogeton strictifolius	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Potamogeton vaginatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7

Table 2. Flora of the benchmark lakes.—Continued

	Prong	Frank	Clear	Pine (c)	Perch	Town Line	Bear-paw	Devils	Alle-quash	Moon	Ano-danta	Pine (w)	Ennis	Ot-tawa	Occurrence (%)
Potamogeton vaseyi	0	0	0	0	0	0	0	1	0	0	0	0	0	0	7
Potamogeton zosteriformes	0	0	0	0	0	0	0	0	1	1	1	0	0	0	21
Potamogeton spp.	1	0	0	1	0	0	0	0	0	0	0	1	0	1	29
Potentilla palustris	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7
Ranunculus reptans	1	0	1	0	0	0	0	0	0	0	0	0	0	0	14
Ranunculus trichophyllus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7
Ranunculus sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7
Sagittaria graminea	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7
Sagittaria latifolia	0	0	0	1	1	1	1	0	1	0	0	0	0	0	36
Sagittaria rigida	0	1	0	0	0	1	0	0	1	0	0	0	0	0	21
Sagittaria spp.	1	1	1	1	0	0	0	0	1	0	1	0	0	0	43
Scirpus americanus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	7
Scripus cyperinus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7
Scirpus validus	0	0	0	1	1	0	0	0	1	0	1	0	0	1	36
Scirpus spp.	0	0	0	0	0	0	0	0	0	0	1	0	1	1	21
Sparganium angustifolium	0	0	0	0	1	0	0	0	1	0	0	0	0	0	14
Sparganium chlorocarpum	0	0	0	0	0	1	0	0	0	0	1	0	0	0	14
Sparganium fluctuans	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7
Sparganium spp.	0	0	1	0	0	0	0	0	0	0	1	0	0	0	14
Spirodela polyrhiza	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7
Typha latifolia	0	0	0	1	0	1	1	0	0	0	1	0	0	1	36
Utricularia geminiscapa	1	0	0	0	0	0	0	0	0	0	1	0	0	0	14
Utricularia gibba	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7
Utricularia intermedia	0	0	0	0	1	0	0	0	1	0	0	0	0	0	14
Utricularia vulgaris	0	0	0	0	0	1	0	0	1	0	0	0	0	0	14
Utricularia spp.	1	0	0	0	0	0	0	0	1	0	1	0	0	1	29
Vallisneria americana	1	0	0	0	0	1	0	1	1	1	1	0	0	1	50
Zanichellia palustris	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Zizania aquatica	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Taxa per lake	24	14	26	21	19	20	15	13	35	13	35	11	10	20	

Table 3. Community attributes in benchmark lakes.*

Group I Lakes	Prong Lake				Frank Lake				Clear Lake			
Scientific Name	*Freq**	*Rfreq***	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*
Brasenia schreberi	51.13	19.49	1.56	30.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isoetes macrospora	31.58	12.04	0.92	11.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sagittaria spp.	32.33	12.32	0.82	10.10	25.00	16.67	0.38	6.33	8.21	5.37	0.19	1.02
Nymphaea tuberosa	25.56	9.74	0.62	6.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nymphaea odorata	21.80	8.31	0.57	4.74	4.17	2.78	0.04	0.11	0.00	0.00	0.00	0.00
Chara spp.	3.76	1.43	0.11	0.16	41.67	27.78	0.46	12.78	11.94	7.80	0.43	3.35
Isoetes spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.10	19.02	0.86	16.36

Group II and III Lakes	Pine(C) Lake				Perch Lake				Town Line Lake			
Scientific Name	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*
Nymphaea odorata	65.85	45.25	1.07	48.42	0.00	0.00	0.00	0.00	84.87	19.49	2.84	55.35
Brasenia schreberi	10.57	7.26	0.22	1.60	50.34	16.19	1.72	27.85	69.74	16.01	2.05	32.82
Myriophyllum farwellii	0.00	0.00	0.00	0.00	66.67	21.45	1.78	38.18	0.00	0.00	0.00	0.00
Utricularia gibba	0.00	0.00	0.00	0.00	63.27	20.35	1.85	37.65	0.00	0.00	0.00	0.00
Utricularia intermedia	0.00	0.00	0.00	0.00	48.30	15.54	1.31	20.36	0.00	0.00	0.00	0.00
Utricularia vulgaris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	78.95	18.13	2.44	44.24
Potamogeton pusillus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.87	8.01	0.86	6.89

Group IV Lakes	Bearpaw Lake				Devils Lake				Allequash Lake			
Scientific Name	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*
Nuphar advena	56.00	33.14	1.67	55.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potamogeton amplifolius	43.00	25.44	0.91	23.15	3.17	1.54	0.09	0.14	20.00	5.76	0.50	2.88
Nymphaea tuberosa	21.00	12.43	0.48	5.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chara spp.	0.00	0.00	0.00	0.00	4.52	2.20	0.06	0.13	14.81	4.26	0.49	2.09
Potamogeton pusillus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myriophyllum spicatum	0.00	0.00	0.00	0.00	54.30	26.43	1.87	49.42	0.00	0.00	0.00	0.00
Potamogeton robbinsii	0.00	0.00	0.00	0.00	49.77	24.23	1.55	37.56	35.56	10.24	0.91	9.32
Elodea canadensis	4.00	2.37	0.09	0.21	45.70	22.25	1.51	33.60	34.81	10.02	0.92	9.22
Ceratophyllum demersum	0.00	0.00	0.00	0.00	9.50	4.62	0.11	0.51	62.96	18.13	1.90	34.45
Zizania aquatica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.63	8.53	0.99	8.44
Vallisneria americana	0.00	0.00	0.00	0.00	8.60	4.19	0.21	0.88	11.85	3.41	0.19	0.65
Myriophyllum verticillatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuphar spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lemna trisulca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Group IV Lakes (Cont.)	Moon Lake				Anadonta Lake			
Scientific Name	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*
Nuphar advena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potamogeton amplifolius	15.07	7.97	0.37	2.95	16.44	2.54	0.34	0.86
Nymphaea tuberosa	0.00	0.00	0.00	0.00	43.11	6.67	1.18	7.87
Chara spp.	30.36	20.29	1.22	24.75	1.78	0.28	0.04	0.01
Potamogeton pusillus	15.07	7.97	0.30	2.39	36.00	5.57	0.94	5.24
Myriophyllum spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potamogeton robbinsii	4.11	2.17	0.05	0.11	5.33	0.82	0.08	0.07
Elodea canadensis	10.96	5.80	0.12	0.70	14.67	2.27	0.26	0.59
Ceratophyllum demersum	0.00	0.00	0.00	0.00	78.67	12.17	2.20	26.77
Zizania aquatica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vallisneria americana	61.64	32.61	1.99	64.89	5.78	0.89	0.11	0.10
Myriophyllum verticillatum	0.00	0.00	0.00	0.00	66.22	10.24	1.69	17.31
Nuphar spp.	0.00	0.00	0.00	0.00	52.44	8.11	1.47	11.92
Lemna trisulca	0.00	0.00	0.00	0.00	45.78	7.08	0.72	5.10

Group V Lakes	Pine (W) Lake				Ennis Lake				Ottawa Lake			
Scientific Name	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*	*Freq*	*Rfreq*	*Aden*	*IV*
Myriophyllum spp.	66.10	50.99	2.58	131.55	0.00	0.00	0.00	0.00	11.87	5.68	0.24	1.36
Chara spp.	35.59	27.45	1.16	31.84	48.64	20.64	1.58	32.61	83.98	40.20	3.25	130.65
Najas flexilis	0.00	0.00	0.00	0.00	57.14	24.24	1.90	46.06	4.75	2.27	0.10	0.23
Potamogeton praelongus	0.00	0.00	0.00	0.00	54.76	23.23	1.64	38.10	0.00	0.00	0.00	0.00
Nuphar variegatum	1.69	1.30	0.04	0.05	31.29	13.28	0.78	10.36	3.86	1.85	0.08	0.15
Scirpus validus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.77	22.87	1.68	38.42

* freq—frequency; rfreq—relative frequency; aden—average density; IV—importance value
**relative frequencies will not add up to 100% because of deleted species

“Red Purge”: The 1946–1947 Strike at Allis-Chalmers

Julian L. Stockley

In 1947, Harold Story, Allis-Chalmers' labor policy engineer and attorney, addressed a convention of the National Association of Manufacturers in New York. He told his audience that, during the 1946–1947 strike at Allis-Chalmers' plant at West Allis, Wisconsin, the company had finally been able to expose what he called the Communist leadership of Local 248:

> Until recently, public opinion has blindly and wholeheartedly supported unionism and collective bargaining. . . .
>
> . . . During Allis-Chalmers' last strike, public opinion changed. Only then was Allis-Chalmers in a position to tell its employees . . . [about] the devastating destructiveness of Communist union leadership in the labor movement.[1]

Story then described how Allis-Chalmers, manufacturers of heavy machinery and farm equipment, had used this shift in public opinion to win the eleven-month strike and break the union. Instead of negotiating the disputed contractual issues that would determine who would control the shop floor and employee loyalty, Allis-Chalmers' management mounted a press campaign against the alleged Communists among Local 248's most active membership. In this way, management sidestepped the contractual points of contention and focused public attention on what they labeled the Communist infiltration in Local 248. Until recently the assertion that Local 248 was Communist dominated has been popularly accepted. But a careful study of the evidence indicates that the charges are unproven and that the company only used them to avoid negotiating a legitimate contractual agreement. It was thus that Allis-Chalmers won the strike and broke the union, dismissed over ninety of the local's most active union members, and forced an unprecedented turnover in Local 248's leadership.

The company found support for its position in the emerging national anti-labor attitude, reflected in and fostered by the local and national press, and in the development of a postwar Red Scare. Allis-Chalmers was also convinced that it had relinquished too much managerial control to Local 248 in the decade before the 1946–1947 strike. From 1936–1946, while the local was building its membership and hoping to gain union securities comparable to those won by like brotherhoods, relations between Allis-Chalmers and Local 248 were strained. The company viewed the 1946–1947 strike as an opportunity for a final showdown.

In 1946 when Local 248 members walked out in the hope of securing wages comparable to national industrial wage rates, an improved grievance procedure, and union security, Allis-Chalmers' management was unwilling to address these contractual points or negotiate a compromise. Local 248 not only had to withstand Allis-Chalmers' managerial pressure, changes in national attitudes, and the press campaign orchestrated by the company, but also had to conduct its strike with reserved support from the leaders of its international, the United Automobile Workers (UAW), and the Congress of Industrial Organizations (CIO) of which the UAW was a member.

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After World War II, the UAW underwent an administrative shift. Its rising leader, Walter Reuther, used the public's perception of a Communist threat to gain the UAW presidency and purge the organization of alleged Communists. The CIO's president, Philip Murray, also employed the Communist issue to purge the federation's ranks. At the same time, the American public was following the House Committee on Un-American Activities' investigations of Communism in labor unions in the United States. It was in this setting that Local 248 attempted to wrest a contract from Allis-Chalmers. After an eleven-month strike, Local 248 was forced to capitulate; employees returned to work without a contract, while the company dismissed Local 248's most active members.

Local 248 was founded in the late 1930s, amid the growing tide of industrial unionism. Up until this time, Allis-Chalmers' West Allis plant had remained unorganized except for a modest membership among the company's selective craft unions, which excluded assembly-line workers. From October 1936 to January 1937, Allis-Chalmers' Federal Labor Union (FLU) 20136, affiliated with the American Federation of Labor (AFL), was under the leadership of Harold Christoffel. During this brief period, members of Allis-Chalmers' AFL trade and craft unions deserted wholesale to the Federal Labor Union, so that by January 1937 the local's membership exceeded 2,000 in a plant of approximately 8,000 employees. Because the newly created Federal Labor Union derived its membership from the assembly-line workers as well as the plant's skilled craftsmen, it came into conflict with the Federated Trade Council in Milwaukee. In March 1937, Allis-Chalmers' FLU 20136 decided to join the newly chartered CIO to become Local 248 UAW-CIO. As an affiliate of the CIO, Local 248 was no longer required to heed craft-union lines while organizing, which allowed for greater growth and flexibility in its intensive organizational program.

The greatest challenge for the new local was Allis-Chalmers' traditional anti-labor stance: Allis-Chalmers had a strike in 1906 and another in 1916, both of which "were crushed by the Company and resulted in the total destruction of the unions."[2] After the implementation of the National Industrial Recovery Act in 1933, the company set up a paternalistic, company-dominated union, the Allis-Chalmers Works Council, which existed from 1933 to 1937 and seated only Allis-Chalmers' most conservative employees. But the council functioned as a grievance board and never held contractual relations with Allis-Chalmers.

Even in the late 1930s, when other firms were moving to open labor-management communications, Allis-Chalmers' management pursued a markedly inflexible labor policy. The firm's executives continued to voice opinions that questioned or rejected labor's role in areas they considered to be under managerial authority, balked at the idea of a closed shop, and opposed any measure that legitimized union authority on the shop floor. Bert Cochran, author of *Labor and Communism,* notes a discrepancy between the company's statements and actions:

> The company maintained that it sincerely accepted collective bargaining, and was pledged to a hands-off policy in the union's internal affairs. Outside observers concluded that it was not the disinterested bystander that it pretended to be. Dr. John Steelman, head of the U.S. Labor Department Conciliation Service, was of the opinion that Max Babb, the company president, was hostile to unions, and in order to keep the CIO off balance, encouraged AFL craft organizations to come into his plants.[3]

It was in this environment that Local 248 attempted to gain recognition as the employees' contractual bargaining agent and won its first nonexclusive contract with the firm in March 1937. After the local won a National Labor Relations Board election in January 1938, Local 248 became the bargaining agent for the employees at the West Allis works.

During the close of the 1930s, the union signed relatively weak contracts compared to the contracts being signed by other UAW locals. Although recognized as the workers' bargaining agent, Local 248 still did not enjoy union security, freedom from management's arbitrariness, or a wage package comparable to those paid by area manufacturers. The contract did not provide a maintenance-of-membership clause to protect the union from membership desertion, nor did the firm dissuade AFL brotherhoods from organizing in the West Allis plant. Allis-Chalmers only agreed to remain "neutral" on the union issue, neither challenging the local directly nor aiding it in securing members. The contracts of the late 1930s also failed to free workers from Allis-Chalmers' arbitrary managerial controls. The company's shop foremen still maintained control over the write-up of employees' grievances, and management retained control over employee dismissals. Nonetheless, this period marked a limited shift in the balance of power on the shop floor at the West Allis works.

The lack of real union security remained a pressing concern for the leadership of Local 248 and was the cause of a seventy-six-day strike in 1941, which was characterized by the national press as a political strike called by the "Communist" leadership of Local 248. However, according to Stephen Meyer, the strike in fact had "all the earmarks of a standard union battle" and was actually called because Allis-Chalmers had been encouraging the AFL to organize in the West Allis works, thus challenging the CIO's Local 248 on the issue of union security.[4] The strike was settled only after the federal government intervened. The issues focused on the labor-management conflict over shop, production, and worker control; yet, more important than this, the 1941 strike introduced the public to and provided the firm with publicized allegations of the Communist Party's influence in Local 248.

During World War II, the labor-management conflict over authority on the shop floor continued as Local 248 attempted to gain recognition as an autonomous power from the company. By using the grievance procedure provided in the contract and taking advantage of the nonpartisan referee assigned to judge these cases, Local 248 was able to modify some contractual boundaries, increase its influence in the shop, and gain a limited amount of managerial authority in the West Allis plant. Had the "Communist" leadership of Local 248 been heeding the advice of such leading Communist figures as Earl Browder, the union would have curtailed its use of the grievance procedure and listened to Browder's urging that "Communists must avoid alienating employers" in order to maximize wartime production. Instead, the local's leadership

> . . . ignored the Party's admonitions to cooperate with management to increase production. Grievances were magnified and, although both union and management had long approved incentive pay, the union stubbornly refused to have it applied to the brass foundry. It also opposed the fifty-six-hour week that the navy had requested to speed up production on navy orders.[5]

Local 248 refused to relent in its struggle for union security, recognition as a legitimate shop power, and economic gains on behalf of its membership. The war afforded the union one gain. In 1943, after the National War Labor Board was called in, Allis-Chalmers was forced to put a maintenance-of-membership clause in the new contract. By guaranteeing that dues-paying members had to maintain paid membership and could not leave the union once they joined, Local 248 was awarded its first contractual clause granting relative union security. The company refused to renew this clause during postwar contractual negotiations.

Wartime relations between Local 248 and Allis-Chalmers were strained, and quite often government agents had to be called in to resolve the contractual disputes of previous years. In the spring of 1946, the local was still negotiating for a contract, which had been under discussion since April 1944 when the previous contract had expired; West Allis employees had been working under the old contract since that time. During the negotiations, Allis-Chalmers ignored the suggested bargaining concessions that the War Labor Board and the Federal Conciliation Service recommended and also ended the referee system that had been used to settle grievances during the war. In an additional show of strength, the company decided to adhere "to its traditional policy which stated that 'no employee's job at Allis-Chalmers shall depend on membership in the Union,'" to its stand on tightening grievance procedures, and to its final wage offer, which was five cents below the national pattern.[6]

As labor-management tensions were nearing strike porportions at its West Allis home plant in the spring of 1946, Allis-Chalmers also faced conflicts with seven out of its eight plants nationwide. By 30 April 1946, Allis-Chalmers had four plants on strike: LaPorte, Indiana; Springfield, Illinois; Norwood, Ohio; and Pittsburgh, Pennsylvania. Three more of its plants went on strike that day: Boston, Massachusetts; LaCrosse, Wisconsin; and West Allis, Wisconsin. Since late 1945, union representatives from various Allis-Chalmers' plants had been meeting with the hope of drawing up a master contract that would cover all of the company's plants. Had Allis-Chalmers accepted the unions' offer to bargain on this scale, the company would have been recognizing the unions as legtitimate, autonomous bargaining partners. But management rejected this idea because it interfered with the company's belief in a fundamental managerial right—the right to decide the terms of the contract offered. After the strike began and as individual unions were forced to settle, Allis-Chalmers sister unions maintained contact through letters, encouraging the locals still out to hold the strike fronts.

Allis-Chalmers also refused Local 248's offer of arbitration because, as Ozanne has observed,

> the party which feels stronger and is anxious to gain something by its power which it fears it might not get from an arbitrator will, of course, refuse arbitration.[7]

Allis-Chalmers was ready for a showdown with the unions that challenged its managerial prerogatives, and the company was especially keen on confrontation with Local 248. As has been pointed out, in its home plant of West Allis, the company evaded the main points of contention: wages, grievance procedures, and union security. Instead, Allis-Chalmers launched a propaganda drive aimed at persuading the public and its West Allis employees that the leadership of Local 248 and its strike were actually a "Communist-inspired plot to disrupt American industry" and that Local 248's "Communist" leadership did not have the workers' best interest at heart.[8]

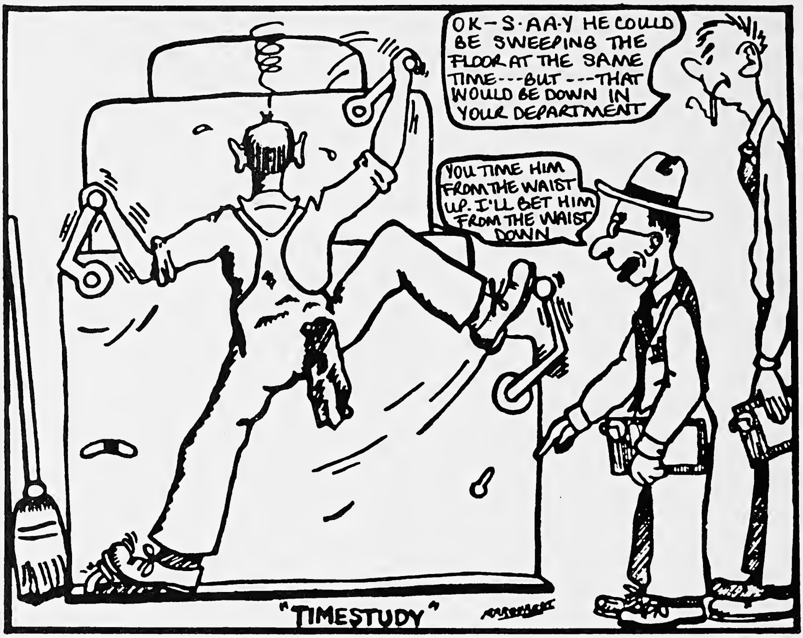
When Allis-Chalmers readied its public relations campaign against Local 248 in 1946, it was addressing a public that had become increasingly concerned about the "Red Bogey" in America, to use David M. Oshinsky's terminology.[9] From the perspective of most American citizens, there seemed to be good reason for alarm over the new "Red menace." While the press highlighted news of Stalin's increasing boldness in Eastern Europe, and of the Canadians exposing a Soviet spy ring, the Truman Administration fueled the nation's frenetic agitation by gearing up for cold war with the newly emerging Soviet enemy. The American people seemed to conclude that although they could not control threats from the outside, they could at least identify and eliminate the enemy within their own ranks.

In 1946, the nation elected the first Republican Congress in eighteen years. Republicans championed the anti-Communist cause, an issue with voter appeal. Lawrence S. Wittner has suggested that American businessmen were the Republican's "keenest supporters" and that they were still "smarting from a generation of social criticism by journalists, news commentators, labor leaders, artists, and intellectuals." In 1946 and 1947, the United States Chamber of Commerce felt the internal Communist threat so keenly that it published the pamphlets "Communist Infiltration in the United States: Its Nature and How to Combat It," "Communists in the Government, The Facts and a Program," and "Communists within the Labor Movement, Facts and Countermeasures." In 1947, the same group put forward the idea that the Justice Department should make public "at least twice a year a certified list of Communist-controlled front organizations and labor unions." The postwar labor strikes foundered under the suspicious eyes of the American public.[10]

During the postwar period, labor unions, many of which had benefited from the organizational skill and commitment of Communist activists, became targets for press "exposures" and Congressional hearings. Under Franklin D. Roosevelt's tutelage ten years earlier, the public explored the possibilities of a cooperative marriage between labor and management as one means of curing depression ills. After the war, however, the public was less willing than it had been during the late 1930s to view labor's courtship in a positive light and often felt as though it had been duped by Communist labor leaders. Sometimes business leaders, organizations, various presses (including the influential Hearst syndicate), and Congressional committees undertook to further their own interests by labeling and exposing the "un-American" elements at the forefront of the American labor movement and by crusading against Communist subversion and subversives. After the 1946–1947 strike at the West Allis plant, Allis-Chalmers' management took pride in its "battle scar" and victory over the union—with the help of the local and national press and two congressional committees—because the company chose "battle with a Communist-dominated union rather than appeasement."[11]

Although Walter Geist, Allis-Chalmers' president, maintained that the "fight was the result of Communist infiltration," he also admitted that the conflict "was to determine whether the company or the union was to run our shops."[12] When the negotiations ended in late April of 1946, the *Wisconsin CIO News: Local 248 Edition* cited ten issues still under contention: discrimination, union security, pay rate, grievance procedure, discipline, layoff, layoff in lieu of transfer, transfers, seniority, and press statements. The three issues that were paramount to the local were the clauses governing union security, grievance procedures, and wages. Each of these was indirectly and directly concerned with shop control. Unable to reach an agreement on any of these issues, and after a strike vote of 8,091 to 251 on 29 April 1946, employees at the West Allis plant walked out.

When the strike began at the West Allis works, both the company and the local, anticipating a final power contest, mo-



From the Wisconsin CIO News: Local 248 Edition, *5 April 1946, p. 8*

bilized their forces and entrenched themselves in their respective positions. The local's mouthpiece, the *Wisconsin CIO News: Local 248 Edition,* ran articles and cartoons that satirized the company's position and outlined the logic of the union's position. Most of the articles and cartoons called attention to instances in which an individual had suffered discrimination or had been refused a contractual right. For example, the paper cited cases in which a foreman had refused an employee the right to call his shop steward in order to file a grievance. In another instance, the paper satirized the company's practice of calling in timestudy experts to determine the rate at which a task should be performed. Often the timestudy experts cut the allowable task time. Thus those employees who were paid not only a base rate, but also according to the number of tasks completed, found the company cropping their wages to fit the projection of the timestudy. Again, the issue was one of shop authority, and the union had no voice in the procedure.

Even before the strike had been authorized at the West Allis works, the rhetorical battles had begun. Walter Geist, the company president, began mailing letters to Allis-Chalmers' employees explaining the company's position. Geist's first set of letters offered members of the "Allis-Chalmers family" assurances that none of their rights as workers were being violated and that wage demands would be met as soon as the Wage Stabilization Board reviewed Allis-Chalmers' wage increase application. The company also sent out a letter to all employees refuting the "claims made in these [Local 248] flyers," which were "examples of irresponsibility and untruthfulness which bring discredit upon the Union and its leadership." The company also claimed Local 248 designed these flyers to "mislead employes into supporting a strike" and that the local was "trying to do this by the propaganda method." From the beginning of the strike, the company's rhetoric was inflammatory; as the strike wore on, the intensity of the propaganda increased greatly.[13]

In the *Wisconsin CIO News: Local 248 Edition,* Local 248 printed responses to the Company letters and to the articles published in the local newspapers. Besides appealing to union membership through these rebuttals, Local 248 printed a book of labor poetry entitled *The Pavement Trail.* The volume came out in June of 1946 and is a good barometer of employee attitudes at the time of the strike. The following example is a satirical profile of Harold "Buck" Story, Allis-Chalmers' executive attorney and labor policy engineer.

Ode to Buck Story

Buck's pictures lately
So royal and stately
Have enhanced our newspaper pages.
No use denying
Old Buck keeps trying
To look like the King of the Sages.

Buck's quite a guy
But there's more meets the eye
In sizing up this venerable gent.
He's tried since the beginning
To give the Unions a skinning;
He's after organized labor hell bent.

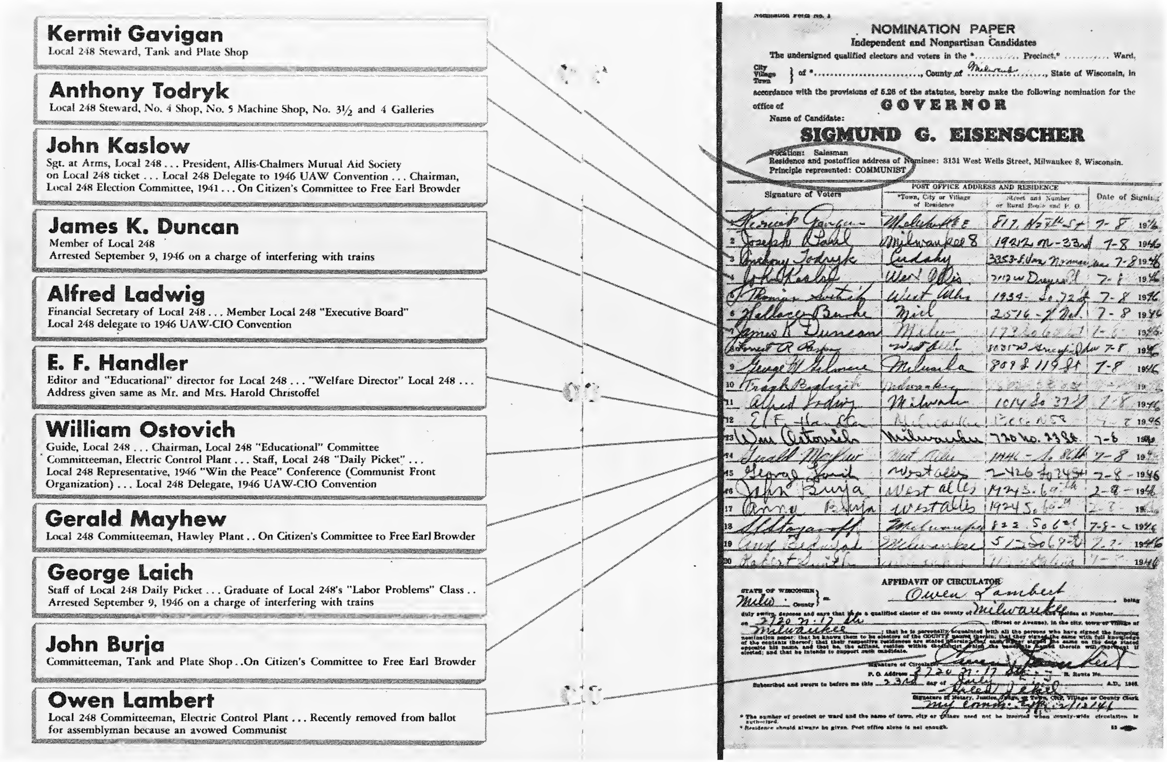
Buck's toothy grin
Is misleading as sin;
He wants the Union forever dissolved.
Don't let him succeed
'Cause brother you'll bleed
All, or nothing at all, he's resolved.

His platinum locks
And loud-colored socks
Could easily put you off guard.
But brother, don't turn
Or your tail-end he'll burn;
He wants Unionism feathered and tarred.

He's a right smart dresser
And at tricks a good guesser
To the public he appears ready and willing.
Old Buck would be good
Were he in Hollywood
As a villain he'd get a number one
billing.[14]

Besides taking jabs at leading Allis-Chalmers' executives, poems and prose in *The Pavement Trail* also satirized the company's anti-union stance, explained their unwillingness to bargain, and served as rousing shows of union solidarity.

After the publication of *The Pavement Trail,* Allis-Chalmers responded with letters to its employees explaining the company's position on the maintenance-of-membership clause and the modification of grievance procedures. In both cases the company demonstrated its desire to maintain control over its employees and the shop floor without having to contend with Local 248. The company maintained that it should have the final say in the case of dismissals and that employees should feel free to come to their foreman with a production problem before seeking a union steward. From a union perspective, the problem with the foreman's maintenance of control over the initial step in the grievance procedure was that it did not protect employees from being coerced back to work or prevent the foreman from simply denying workers' complaints. In September 1946, the letters sent out by Allis-Chalmers changed tone. Instead of continuing to outline the company's stance on contractual differences, the letters informed employees that other plants were already returning to work after having settled and that some of the West Allis works' employees were asking, "Can I go back to work?"[15]



Kermit Gavigan
Local 248 Steward, Tank and Plate Shop

Anthony Todryk
Local 248 Steward, No. 4 Shop, No. 5 Machine Shop, No. 3½ and 4 Galleries

John Kaslow
Sgt. at Arms, Local 248 . . . President, Allis-Chalmers Mutual Aid Society on Local 248 ticket . . . Local 248 Delegate to 1946 UAW Convention . . . Chairman, Local 248 Election Committee, 1941 . . . On Citizen's Committee to Free Earl Browder

James K. Duncan
Member of Local 248
Arrested September 9, 1946 on a charge of interfering with trains

Alfred Ladwig
Financial Secretary of Local 248 . . . Member Local 248 "Executive Board"
Local 248 delegate to 1946 UAW-CIO Convention

E. F. Handler
Editor and "Educational" director for Local 248 . . . "Welfare Director" Local 248 . . .
Address given same as Mr. and Mrs. Harold Christoffel

William Ostovich
Guide, Local 248 . . . Chairman, Local 248 "Educational" Committee
Committeeman, Electric Control Plant . . . Staff, Local 248 "Daily Picket" . . .
Local 248 Representative, 1946 "Win the Peace" Conference (Communist Front Organization) . . . Local 248 Delegate, 1946 UAW-CIO Convention

Gerald Mayhew
Local 248 Committeeman, Hawley Plant . . On Citizen's Committee to Free Earl Browder

George Laich
Staff of Local 248 Daily Picket . . . Graduate of Local 248's "Labor Problems" Class . .
Arrested September 9, 1946 on a charge of interfering with trains

John Burja
Committeeman, Tank and Plate Shop . . On Citizen's Committee to Free Earl Browder

Owen Lambert
Local 248 Committeeman, Electric Control Plant . . . Recently removed from ballot for assemblyman because an avowed Communist

NOMINATION PAPER
Independent and Nonpartisan Candidates
The undersigned qualified electors and voters in the *.......... Precinct,* .... Ward, City Village Town of *........................, County of Milwaukee, State of Wisconsin, in accordance with the provisions of 5.26 of the statutes, hereby make the following nomination for the office of **GOVERNOR**
Name of Candidate:
SIGMUND G. EISENSCHER
Vocation: Salesman
Residence and postoffice address of Nominee: 3131 West Wells Street, Milwaukee 8, Wisconsin.
Principle represented: COMMUNIST

Signature of Voters	Post Office Address and Residence: *Town, City or Village of Residence	Street and Number or Rural Route and P. O.	Date of Signing

AFFIDAVIT OF CIRCULATOR
STATE OF WISCONSIN, Milw. County } ss. Owen Lambert being duly sworn, deposes and says that he is a qualified elector of the county of Milwaukee ...

The complete flyer may be found in either the Don D. Lescohier Papers or the Harold W. Story Papers.

September 1946 marked the beginning of a more urgent phase in the rhetorical battle of the strike. It was in September that the *Milwaukee Sentinel* began running a fifty-nine–day series of articles examining Communist involvement in the Wisconsin State CIO Council and the Milwaukee County CIO Council. The articles were signed by "John Sentinel," which was "supposedly the pseudonym for a Sentinel reporter," but was actually the pseudonym for an Allis-Chalmers researcher. As the largest CIO union in the state, Local 248 was involved in shaping the policies of both CIO councils. For instance, Local 248's president, Robert Buse, was also president of the Milwaukee County CIO Council. Not only did the state and county CIO organizations come under attack, but so did Local 248's leadership. Using an old offensive tactic, Allis-Chalmers and the municipal police worked closely with the press to construct cases that would incriminate the "Communists" within Local 248 and its leadership.[16]

In October, even though picketing workers had told Walter Geist to "save your postage," Allis-Chalmers continued sending letters trying to start a back-to-work movement. One letter claimed that over 2,500 had already returned to work. Despite having been on strike for five months, Local 248's membership rallied around the returning Harold Christoffel, Local 248's honorary president and founder, who had just returned from military duty. The strike would continue for another six months.

In the middle of October, the company mailed a pamphlet to its employees; the pamphlet cover stated, "Principle represented: COMMUNIST" and then asked, "Would you sign *YOUR* name under this?" The pamphlets were a collection of selected gubernatorial nomination papers for Sigmund E. Eisenscher, whose supporters had circulated his nomination papers on the Allis-Chalmers' picket line. Members of Local 248 who had signed the papers had their signatures pinpointed on the nomination papers and, on the facing page, found their full names with a personal sketch outlined in a bold red block. Allis-Chalmers' management accepted this as proof that Local 248's most active members were Communists.[17]

In the next issue of the *Wisconsin CIO News,* members of Local 248 explained their signatures:

> "I signed because I believe anyone who wants to run for office has a right to. . . ."
>
> "Since when is it illegal to sign nomination papers? I signed all kinds of nomination papers this year—for Republicans, Democrats and Socialists, and the company didn't single me out for signing them. . . ."
>
> "I believe in democracy, and that means free elections and the right of people of all political beliefs to run for office. That's why I signed Eisenscher's papers. . . ."[18]

These statements were not given the press circulation that the Communist charges received in area and national papers. The Milwaukee area, as well as the nation, was exposed chiefly to media stories that were based on information furnished by Allis-Chalmers. As the company's media campaign picked up, the local's popular support dropped.

In the first issue of November, the *Wisconsin CIO News: Local 248 Edition* carried a cartoon entitled "Time Stands Still," which equated Allis-Chalmers' management with the witch hunters of Salem. Still, the paper's sardonic humor could not counter Allis-Chalmers' public press charges against Local 248's leadership, waning popular support, and dropping strike contributions. It is at this point that the lack of support from Local 248's international became critical. The UAW's newly elected president, Walter Reuther, in order to gain his office had pledged to purge the UAW ranks of Communists—in spite of his own leftist sympathies. Because of this pledge and, perhaps even more important, because he could not set aside his personal loathing of Local 248's founder and honorary president, Harold Christoffel, or his "machine," Reuther withheld the international's full support.[19]

Even the CIO offered Local 248 only halfhearted support. Philip Murray, the CIO's president, had never been able to work with Communist members of the CIO in the same detached manner that former CIO president John L. Lewis had. Lewis used to "wave aside charges that he was harboring Communists with the comment, 'I do not turn my organizers or CIO members upside down and shake them to see what kind of literature falls out of their pockets.'" Murray, being staunchly conservative and a devout Catholic, was repulsed by CIO Communists and their fellow travelers. In fact, Murray and his friends often sneered at "pinkos" like Reuther. Following the war, there was growing pressure on Murray to purge the CIO.[20]

As the 1946–1947 strike reached its climax in the final months of 1946, Walter Reuther offered the local the assistance of the UAW's former president and current vice-president, R. J. Thomas, although Reuther himself did not become directly involved. Philip Murray also failed to take an active role in the local's fight and, for the most part, remained aloof from the strike. This lack of wholehearted, visible support from both the UAW and the CIO was another factor contributing to the eventual loss of the strike. It seemed as though the national union leaders viewed Local 248's desperate situation as an opportunity to oust the union's leaders.

At the beginning of November, R. J. Thomas came to West Allis in order to give the public a show of UAW support. November was marked by the most public displays of the local's power and shows of force by the municipal police: large parades were organized, more strikers were placed on picket duty, and the police force became more visible. The UAW and the CIO called on other unions to offer their support to the striking Allis-Chalmers' workers. Members of area locals would often join strikers on the picket line or parade. The UAW's largest local, Local 600 from the Ford plant in Michigan, sent its key union members with their "sound truck" so that Local 248 would get an opportunity to tell its story to the Milwaukee public.

R. J. Thomas also served as a negotiator during the November talks with Allis-Chalmers. Members of the UAW's executive board accused the company of using the Communist charges to sidestep the contractual issues under contention. Even after talks were moved to Chicago for the convenience of the federal negotiators, the company remained "defiant" and in an off-the-record comment said that "they had the strike won; their propaganda barrage had borne fruit and that public opinion was in their favor." The talks ended at the beginning of December; Thomas said that bargaining with the company was like "bargaining with a stone wall." Additional reports from UAW representatives stated that employee wages at Allis-Chalmers were below area industrial wages and, again, stated that the company was avoiding the real issues under contention in favor of the Communist "hype."[21]

The strike continued into December with little change. The number of demonstrations picked up and so did police involvement. There were incidents of violence on the picket lines. In December, Allis-Chalmers dismissed Robert Buse, Local 248's president, and Joseph Dombek, Local 248's vice-president, for making statements against the company. Finally, at the end of the month, after a

Taken during the height of picket-line violence in the winter of 1946, the photograph was part of the evidence submitted by Allis-Chalmers during the 1947 congressional hearings as purportedly showing Communist-inspired violence.

series of political maneuvers involving charges of rigged elections, state CIO positions were lost by officers sympathetic to Local 248. Letters from other Allis-Chalmers' locals continued to encourage Local 248 to hold out even though all other striking locals had been forced to sign contracts in order to preserve their unions. Despite the encouragement from other locals, Local 248's strike power was declining.

By January 1947, Allis-Chalmers refused to bargain with Local 248's leadership and refused Thomas' offer to submit the dispute to arbitration. The company waited until an independent union formed and called the Wisconsin Employment Relations Board (WERB) for a representative vote within Local 248. Following this direct challenge to Local 248's bargaining and plant authority, telegrams were sent and announcements made in support of the local by the UAW's and the CIO's two most obviously silent members: Philip Murray and Walter Reuther offered the local encouragement and also told strikers that only a vote for Local 248 would win the strike. After the local won the WERB election by only a narrow margin, some ballots were challenged by the WERB, of which Harold Story, the Company's attorney, was a member, according to the local's newspaper. Local 248 was again confronted with the possibility of having to face another election.[22]

While Local 248 held its officer elections during the last part of February and saw all of its incumbent officers reelected, Allis-Chalmers, working in conjunction with the editor of the *Milwaukee Sentinel,* invited the Committee on Un-American Activities and the Committee on Education and Labor to investigate what the company alleged to be the Communist leadership of Local 248. The hearings before the Committee on Un-American Activities began in Washington, D.C. at the end of February and concentrated on interviewing opponents of Local 248 and its leadership. At the beginning of March, hearings began in Milwaukee before the Committee on Education and Labor, which focused on Local 248's most active members. While investigating Communism in American labor unions, the hearings concluded, based on guilt by association, that certain members of Local 248 were Communists. Both the *Milwaukee Sentinel* (a member of the Hearst syndicate) and the *Milwaukee Journal* gave the hearings primary coverage. The final cooperative push by Allis-Chalmers' management, the *Milwaukee Sentinel,* and the Congressional committees played a major part in breaking the strike and led to the expulsion of Local 248's leadership.[23]

By the beginning of March, there were an estimated 5,000 workers back in the West Allis plant. Local 248 continued the strike, despite the continued attacks from Allis-Chalmers' management, the local and national press, and Congressional hearings, and despite only halfhearted support from the UAW and the CIO. Moreover, after the state and county CIO conventions elected less sympathetic officers, the strikers faced diminished support from their own area locals. At the end of March, Harold Christoffel was discharged by Allis-Chalmers, and Local 248 sent its officers to meet with UAW-CIO heads in order to discuss proposals to break the stalemate. On 24 March 1947, employees returned to work without a contract.

On the day that the strike ended, Walter Geist sent a letter to all employees announcing "THE STRIKE IS OVER!" and outlining, once again, the company position:

> . . . we will continue to fight with all our strength against those who try to undermine the relations between you and the Company.[24]

The eleven-month strike had been a contest over the control of employee loyalty and the West Allis plant. Yet, most of the rhetoric surrounding the strike concerned itself with the Communist issue: the company's accusations and the local's refutations.

Although the *Wisconsin CIO News* reported "248 Surprise Move Throws A-C in Panic," the decision to return to work without a settlement was, in fact, a last effort to save Local 248 before the company called another WERB representative election.[25] In a letter to Allis-Chalmers' employees, Walter Geist summed up the strike in this fashion:

> As the Company prospers we will prosper with it. By the Company I mean every man and woman on the payroll because *you are the Company.* You are Allis-Chalmers. Together we are a big family—there are 29,000 of us.
>
> In the lives of nearly every family there comes a time at home when little frictions develop. We recognize these things as a normal part of living together, but we don't let people on the outside of our own family circle magnify these differences. . . .
>
> . . . It is important, however, that all of us keep in mind the motives of those who attempt to magnify our differences in an effort to destroy our friendly relations and to promote an outside selfish interest.[26]

The letter's tone indicates that even after the strike Allis-Chalmers' president still desired to foster a paternalistic company-employee relationship. From Geist's perspective, Local 248 and its leadership were outsiders who had disrupted the development of an Allis-Chalmers' employee family. By mid-April, over ninety of Local 248's most active members, most of whom were longstanding Allis-Chalmers' employees, were dismissed by the company in an effort to remove the perceived threat. In a *Milwaukee Journal* interview, Walter Geist said that it was a "tonic" for him to see the plant running again and did not feel there would be any more difficulties now that the "troublemakers" were gone.[27]

Because some of the dismissed union members were also those who were elected to bargain with Allis-Chalmers, the company's management refused to bargain with the selected committee. Walter Reuther, UAW president, came to Milwaukee to discuss an agreement with Allis-Chalmers without notifying Local 248's leadership, thus undermining any hope of recovery that the local's leadership had harbored. Shortly after the UAW's fall convention in 1947, Reuther placed Local 248 under administratorship.

In November 1947, Pat Greathouse was chosen to serve as Local 248's administrator. In February 1948, Reuther extended his administratorship to ensure that the "recalcitrant local" would be brought into his camp. Before his departure in July, Greathouse had scheduled new officer elections, appointed interim stewards, and had filed charges against thirteen former Local 248 officers for misappropriation of funds. Then, in that same year, after new union officers conducted an inquiry, Harold Christoffel and key members of his administration were expelled from Local 248. Public opinion had changed. And Allis-Chalmers had succeeded in forcing the removal of "the devastating destructiveness of Communist union leadership" in Local 248.

Endnotes

[1] Harold Story, "Address to the National Association of Manufacturers"; cited in Robert W. Ozanne, "The Effects of Communist Leadership on American Labor Unions" Ph.D. dissertation, University of Wisconsin—Madison, 1954, pp. 232–233.

[2] Ozanne, "The Effects of Communist Leadership," p. 189.

[3] Bert Cochran, *Labor and Communism: The Conflict that Shaped American Unions* Princeton: Princeton University Press, 1977, p. 169.

[4] Stephen Meyer, "The State and the Workplace: New Deal Labor Policy, the UAW, and Allis-Chalmers in the 1930s and 1940s," paper prepared for NEH-funded Research Conference, Dekalb, Illinois, 10–12 October, 1984, pp. 15–16.

[5] Harvey Levenstein, *Communism, Anti-communism, and the CIO.* Westport, Connecticut: Greenwood Press, 1981, pp. 162, 174.

[6] See *Wisconsin CIO News: Local 248 Edition,* 4 January 1946, p. 8; 15 February 1946, p. 8; Cochran, *Labor and Communism,* p. 272; Walter F. Peterson, *An Industrial Heritage: Allis-Chalmers Corporation.* Milwaukee: Milwaukee County Historical Society, 1976, p. 343.

[7] Ozanne, "The Effects of Communist Leadership," p. 235.

[8] David M. Oshinsky, *Senator Joseph McCarthy and the American Labor Movement.* Columbia: University of Missouri Press, 1976, p. 30.

[9] See David M. Oshinsky, *A Conspiracy So Immense: The World of Joe McCarthy.* New York: Free Press, 1983. Chapter Six for a discussion of the Red Bogey in America.

[10] Lawrence S. Wittner, *Cold War America: From Hiroshima to Watergate.* New York: Praeger Publishers, 1974, p. 88.

[11] Peterson, *An Industrial Heritage,* p. 345.

[12] Walter Geist, *Allis-Chalmers: A Brief History of 103 Years of Production.* Princeton: Princeton University Press for Newcomen Publications, 1950, p. 23.

[13] See Walter Geist to All Men and Women of Allis-Chalmers, 17 April 1946; W. C. Van Cleaf to Allis-Chalmers Workers' Union, 25 April 1946, Box 1, Folder 5, Don D. Lescohier Papers, Wisconsin State Historical Society, Madison, Wisconsin.

[14] From *The Pavement Trail: A Collection of Poetry and Prose from the Allis-Chalmers Picket Lines, 1946,* Adolph Germer Papers, WSHS, Madison, Wisconsin.

[15] See W. C. Van Cleaf to All Employes at the West Allis Works, 19 June 1946; 25 July 1946; 20 September 1946, Box 1, Folder 5,

DDL Papers, WSHS, Madison, Wisconsin.

[16] See Levenstein, *Communism, Anticommunism, and the CIO,* pp. 236, 248 and Cochran, *Labor and Communism,* p. 273.

[17] The majority of secondary sources that discuss either the 1941 or 1946–1947 strikes at Allis-Chalmers work under the assumption that officers of Local 248 were Communists. These same sources cite Robert Ozanne's dissertation as their major source, but also cite newspaper articles, Congressional hearings, or the gubernatorial nomination papers circulated on the Allis-Chalmers' picket lines during the 1946–1947 strike. In his 1954 dissertation, Ozanne uses all of the sources mentioned as well as anonymous interviews in an attempt to prove that Harold Christoffel and members of his administration were Communists.

Ozanne failed to take into consideration that the area and national press and Congressional committees worked in close association with Allis-Chalmers, which had something to gain by ousting the longstanding leadership of Local 248. Ozanne's reliance on anonymous interviews which, given the time frame and the fact that they were probably granted by rivals of the Christoffel administration, may be discredited as well. The one piece of evidence that may have proved convincing to Ozanne was the gubernatorial nomination papers that members of Local 248 signed. He did not consider, however, that nomination papers can be signed by any voter of any party affiliation and that they were circulated on the picket lines during the 1946–1947 strike. And as Sigmund G. Eisenscher, the Communist gubernatorial candidate, points out in a letter to R. J. Thomas: "The only persons involved who had in any way pledged themselves to support my candidacy as such were those who *circulated* the petitions—not the signers."*

* (Sigmund G. Eisenscher to R. J. Thomas, 14 February 1947, Box 1, Folder "Correspondence, 1941–1951," Fred Basset Blair Papers, WSHS, Madison, Wisconsin.)

[18] *Wisconsin CIO News,* 18 October 1946, p. 1.

[19] Levenstein, *Communism, Anticommunism, and the CIO,* pp. 83–84, 199–200.

[20] Cochran, *Labor and Communism,* pp. 97, 265–267.

[21] See *WI CIO: 248,* 8 November 1946, p. 8; *WI CIO News,* 15 November 1946, p. 3; 22 November 1946, pp. 1, 3; 29 November 1946, p. 3.

[22] See *WI CIO News,* 10 January 1947, p. 3; 17 January 1947, pp. 1, 4, 4A; 31 January 1947, p. 3; 14 February 1947, p. 3; 21 February 1947, p. 1.

[23] See *WI CIO News,* 14 February 1947, p. 1; *WI CIO: 248,* 28 February 1947, p. 8; Levenstein, *Communsim, Anticommunism, and the CIO,* pp. 242, 246.

[24] Walter Geist to All Employes at West Allis Works, 24 March 1947, Box 1, Folder 5, DDL Papers, WSHS, Madison, Wisconsin.

[25] See *WI CIO News,* 28 March 1947, p. 2 and Cochran, *Labor and Communism,* p. 275.

[26] Walter Geist to All Employes at West Allis Works, 4 April 1947, Box 1, Folder 5, DDL Papers, WSHS, Madison, Wisconsin.

[27] See *WI CIO: 248,* 11 April 1947, p. 8; *WI CIO News,* 18 April 1947, p. 1; and *Milwaukee Journal,* Business Section, 6 April 1947, p. 11.

Primary Sources

In order to provide a contrast and complement to secondary sources that examine the 1946–1947 strike at Allis-Chalmers, this paper's primary sources are *The Wisconsin CIO News* 1945–1948 and *The Wisconsin CIO News: Local 248 Edition* 1945–1947, Local 248's press. The *Milwaukee Journal* 1946–1947 and the *Milwaukee Sentinel* 1946–1947 were also consulted, but are used thoroughly in Ozanne's dissertation. Manuscript collections of Fred Basset Blair, Adolph Germer, Don D. Lescohier, and Harold W. Story were also consulted. These collections are housed by the Wisconsin State Historical Society in Madison. The Lescohier Papers contain the official letters of Allis-Chalmers that are addressed to its employees and the Local during the strike years; the Story Papers contain the official testimony of Allis-Chalmers' officials before the Congressional committees in 1947. Government documents consulted were the Congressional hearings before the Committee on Un-American Activities, *Hearings Regarding Communism in Labor Unions in the United States,* 80th Cong., 1st sess., 1947 and Congressional hearings before the Committee on Education and Labor, *Amendments to the National Labor Relations Act, Hearings on Bills to Amend and Repeal the National Labor Relations Act, and for Other Purposes,* 80th Cong., 1st sess., 1947.

Secondary Sources

The most thorough accounts of the 1946–1947 strike at Allis-Chalmers are covered in three unpublished sources: Robert W. Ozanne's 1954 Ph.D. dissertation, "The Effect of Communist Leadership on American Labor Unions," for the University of Wisconsin-Madison; Richard L. Pifer's 1983 Ph.D. dissertation, "Milwaukee Labor During World War II: A Social History of the Homefront," for UW-Madison; and Stephen Meyer's 1984 paper, "The State and the Work Place: New Deal Labor Policy, the UAW, and Allis-Chalmers in the 1930s and 1940s," prepared for an NEH-Funded Research Conference. Ozanne's dissertation is the Local 248 primer, providing valuable background information on the history of Local 248 and its relations with Allis-Chalmers, but the work fails to maintain a scholarly perspective in its commentary about the 1941 strike and subsequent events. Pifer's dissertation provides the most thorough coverage of wartime relations between Local 248 and Allis-Chalmers' management, placing the conflicts in the context of an industrial struggle, not a struggle against Communism. Likewise, Meyer's paper highlights the Allis-Chalmers/Local 248 conflict as a struggle over managerial control. Meyer proves the best secondary source for information and commentary on the 1946–1947 strike.

Published secondary sources that provide peripheral coverage of the strike or more general histories of labor in Wisconsin include Thomas W. Gavett's *Development of the Labor Movement in Milwaukee,* Howell John Harris' *The Right to Manage: Industrial Relations Policies of American Business in the 1940s'* Robert W. Ozanne's *The Labor Movement in Wisconsin: A History,* and Walter Peterson's *An Industrial Heritage: Allis-Chalmers Corporation,* the official history of Allis-Chalmers.

Both Bert Cochran's *Labor and Communism: The Conflict that Shaped American Unions* and Harvey Levenstein's *Communism, Anticommunism, and the CIO* are excellent histories of the growth of American labor unions and leftists' involvement. Both books also provide insights into the roles of the UAW and the CIO in determining the outcome of the 1946–1947 Allis-Chalmers strike. The books *Senator Joseph McCarthy and the American Labor Movement, A Conspiracy So Immense: The World of Joe McCarthy,* both by David M. Oshinsky, and *Cold War America: From Hiroshima to Watergate* by Lawrence S. Wittner, examine the national climate at the time of the strike. Oshinsky and Wittner provide insights into the roots and causes of America's second postwar Red Scare and America's reactions to the perceived Communist threat.

Fishes of the Upper Trout River, Vilas County, Wisconsin

John Lyons

Abstract. *The Trout River, a small warm-water river in north-central Wisconsin, contains a rich assemblage of fishes over the upper 7.5 kilometers of its length. The river has at least 36 species, 62% of the total number reported for Vilas County. One short stretch contains at least 29 species and another contains at least 25, which is greater than the number encountered at over 99% of 1151 stretches on similarly sized streams and rivers in southern and western Wisconsin. Four of the species found in the Trout River, the pugnose shiner* (Notropis anogenus), *the greater redhorse* (Moxostoma valenciennsi), *the northern longear sunfish* (Lepomis megalotis pelastes), *and the least darter* (Etheostoma microperca), *are rare in all parts of Wisconsin, while two others, the banded killifish* (Fundulus diaphanus) *and the fantail darter* (Etheostoma flabellare), *are rare in north-central Wisconsin. The Trout River should be managed primarily to protect its unusual fish fauna and wilderness characteristics and secondarily to increase its recreational use.*

North-central Wisconsin has a large number and diversity of lakes, streams, and rivers. The fish populations of the lakes have been heavily studied since the turn of the century, but the fish populations of the streams and rivers have received much less attention. Studies of streams have been restricted for the most part to waters cold enough to support trout. Warm-water streams and rivers in the region have been essentially ignored by biologists; species lists for most of these streams and rivers are incomplete, and in many cases even the presence or absence of major gamefish species is uncertain (Black et al. 1963).

Fishing pressure is heavy in north-central Wisconsin, and many lakes in the region are crowded with anglers, boaters, and swimmers during certain times of the year. One possible way to relieve this congestion, as well as to increase recreational opportunities, is to develop and promote fishing and boating in warm-water streams and rivers (Wisconsin Department of Natural Resources 1979). At present, warm-water streams and rivers in north-central Wisconsin are little-used relative to lakes. Development and promotion of fishing opportunities in these streams and rivers requires an evaluation of their potential fishery resources. The first part of such an evaluation is a description of fish species composition and relative abundance.

Data on the fishes of warm-water streams and rivers in north-central Wisconsin is also necessary in order to preserve rare and endangered species. The distribution and abundance in north-central Wisconsin of the fishes on Wisconsin's Endangered, Threatened, and Watch Lists is poorly known. Elsewhere in Wisconsin most of the fishes on these lists are limited to warm-water streams and rivers (Becker 1983).

In this paper, I present the results of the first detailed survey of the fishes of the

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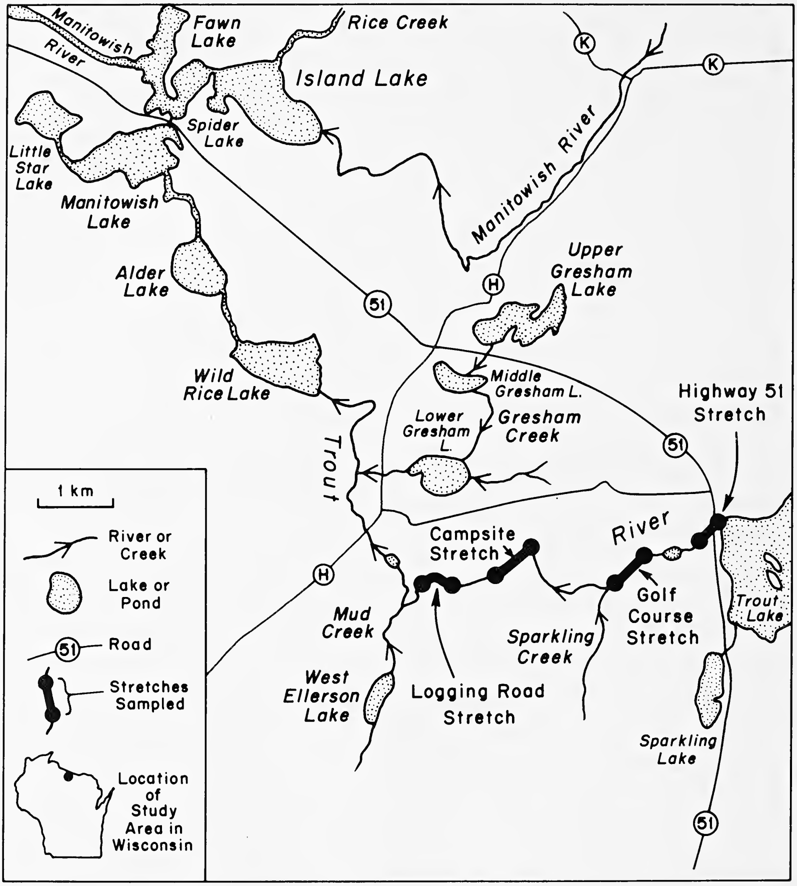

Fig. 1. Map of the Trout River and vicinity, showing sampling locations. For clarity, only rivers and lakes directly connected with the Trout River are shown.

Trout River, a small warm-water river in north-central Wisconsin. Almost nothing is known about the fishes of this river, although the high potential value of the river for angling was recognized over twenty years ago (Black et al. 1963).

Study Area

The Trout River is located in central and western Vilas County (Fig. 1). The river arises from Trout Lake and flows 22 kilometers west and north to its confluence with Manitowish Lake and the Manitowish River. Water from the Trout River ultimately empties into the Mississippi River. Over the upper 11 kilometers of its length the Trout River receives water from three permanent tributaries, whereas over the lower 9 kilometers the river flows through three lakes. Four permanent tributaries drain into Trout Lake and could be considered the headwaters of the Trout River.

I sampled only in the upper 7.5 kilometers of the Trout River, from the outlet at Trout Lake to a logging road bridge located about 2 kilometers upstream of the County Highway H bridge (Fig. 1). I sampled within four stretches: 1) a 0.5 kilometer stretch between Trout Lake and the State Highway 51 bridge (Highway 51 stretch), 2) a 1 kilometer stretch just above the river crossing at the Trout Lake Golf Course (golf course stretch), 3) a 1 kilometer stretch adjacent to the wilderness campsites along the river (campsite stretch), and a 0.5 kilometer stretch just above the logging road bridge (logging road stretch). Within each stretch, I sampled a total of approximately 200 meters of the river.

The Highway 51 stretch consists of short deep pools alternating with short deep riffles and runs. Maximum depth of pools is 1.8 meters, while the average width of the river is about 8 meters. Substrate is gravel and cobbles with some sand. Large woody debris are common in and along the river, but macrophytes are rare. Conifer forests line both banks; these banks are low and marshy. Current is swift (up to 1 m/sec) and strong.

The golf course stretch contains varied habitat. Some parts of the stretch are slow-moving (<0.1 m/sec), 15 to 25 meters wide, and up to 2 meters deep. At the head of the stretch the river has formed a pond-like area of several hectares. Bottom substrates are sand and silt, both submerged and emergent macrophytes are common, and the banks are low, marshy, and lined with shrubs. Other parts of the golf course stretch are similar to the Highway 51 stretch with alternating pools, riffles, and runs, and areas of fast current. These parts of the golf course stretch average about 12 meters in width and have a maximum depth of 1.2 meters. Substrate is gravel and cobbles, macrophytes are scarce, and the banks are lined with a mixed hardwood-conifer forest.

The campsite stretch has few riffles and consists mainly of long pools and runs with moderate current (0.1 to 0.6 m/sec). Width averages 12 meters and maximum depth is 1.3 meters. Substrate is sand and gravel, with a few cobbles and boulders. Large woody debris and submerged and emergent macrophytes are common. A mixed conifer-hardwood forest lines the banks.

The logging road stretch also has few riffles and a moderate current. Width averages 11 meters and maximum depth is 2.2 meters. Substrate is sand and gravel, with silt in areas of slower current. Submerged macrophytes are common and emergent macrophytes line the banks. A mixed conifer-hardwood forest covers the upland away from the river.

Water quality in the Trout River is excellent. The water in the river is very clear and rarely becomes turbid, even after heavy rains. The only permanent human habitation along the upper part of the river is the golf course, and here a buffer zone of undisturbed vegetation appears to minimize runoff and erosion into the river. The forests in the vicinity of the river are regularly logged, and erosion from clear-cut areas could have a negative impact on water quality. However, from the appearance of the forests, the area within a few hundred meters of the river has not been logged in many years, so logging impacts on the river are probably low. The Trout River has slightly alkaline water, with a pH of 7.5, a methyl-orange alkalinity of 41 mg/1, and a conductivity of 87 umhos/cm (Black et al. 1963).

Methods and Materials

I sampled the Trout River for fish from 1980 through 1984, although I did not sample every stretch in every year. All my sampling occurred between mid-May and early October.

I used a variety of gears to sample each stretch. In riffles and other areas of swift current, my primary sampling gears were seines (3.2 or 6.4 mm stretch mesh) and a direct-current backpack electroshocker. In slower-moving water, I also used fyke nets (0.8 m diameter hoops, 10 cm throats, 6.4 mm stretch mesh, 4.6 m leads), dip nets, minnow traps, angling, and visual observations.

Effort and sampling techniques varied from date to date and from stretch to stretch. I expended the most sampling effort at the Highway 51 and campsite stretches, and the least at the golf course stretch. My goal was not to collect detailed quantitative data during each day of sampling, but rather to capture at least one individual of each species present within each stretch and to get a general idea of their relative abundance. I had three abundance categories: common—almost always captured or observed, usually in large numbers (>50 individuals); present—regularly captured or observed, but usually in low numbers (<10 individuals); and uncommon—captured only once or twice, and always in low numbers.

I identified to species and counted all fish that I captured or observed. I preserved one or more individuals of most species that I captured and deposited these specimens in the University of Wisconsin Zoological Museum (UWZM).

I developed species lists and relative abundances for each stretch based on my collections, supplemented with collections made by University of Wisconsin-Madison Field Zoology students during the 1960s and 1970s [UWZM specimens and the Wisconsin Department of Natural Resources (WDNR) Fish Distribution Survey Database (Fago 1984)]. I also developed species lists for areas upstream (Trout Lake and tributaries) and downstream (Manitowish Lake) of the Trout River, using my own collections, collections by other University of Wisconsin-Madison and WDNR personnel, UWZM specimens, the WDNR Fish Distribution Survey Database, Greene (1935), Becker (1983), and Lyons (1984). I also surveyed or requested information on holdings of Trout River fishes in the collections of the Bell Museum of Natural History, Minneapolis, Minnesota, the Milwaukee Public Museum, the University of Michigan Museum of Zoology, Ann Arbor, the University of Wisconsin-Stevens Point Museum of Natural History, and the United States National Museum, Washington, D.C. However, none of these museums had specimens from the Trout River.

Results

I captured 36 species of fish, in 11 families, from the Trout River (Table 1). The dominant families, in terms of number of species, were Cyprinidae (14 species), Centrarchidae (6 species), and Percidae (6 species). The dominant species, in terms of distribution and relative abundance, were the common shiner and the hornyhead chub (Table 2). The most widespread and abundant panfish were the rock bass and the yellow perch. I captured many large rock bass and bluegills, but relatively few large gamefish.

The 36 species that occur in the Trout River represent 62% of the total number of species known from Vilas County (Greene 1935; Becker 1983; WDNR Fish Distribution Survey Database, personal observations). If species that are restricted to lakes or cold water (<22 C) are not counted, the percentage jumps to 73. Sixteen species reported from either upstream or downstream from the Trout River are absent from the Trout River itself (Table 1); most of these species are restricted to lakes or cold water.

The campsite stretch had 29 confirmed species, while the logging road stretch had 25. Most stretches on similarly sized streams and rivers in Wisconsin do not have as many species. The WDNR Fish Distribution Survey sampled 1151 stretches between 5 and 50 m in average width throughout the southern and western halves of Wisconsin, and only one stretch (Mukwanago River, below Phantom Lake, Waukesha County) had more than 29 species (WDNR Fish Distribution Survey Database). Less than one percent of the 1151 stretches had 25 or more species.

The Trout River contains four species, the pugnose shiner, the greater redhorse, the northern longear sunfish, and the least darter, that are rare in Wisconsin (Becker 1983, personal communication; WDNR Fish Distribution Survey Database). The pugnose shiner is on the watch list in Wisconsin (WDNR Bureau of Endangered Resources unpublished data), which means that, while not in immediate danger of extirpation, this species is rare in the state and needs to be regularly monitored to determine whether its population remains stable (Les 1979). The pugnose shiner is found only in the north-central United States and southern Ontario and is nowhere common (Gilbert 1980). This species typically occurs in clear, weedy streams and lakes. These types of habitats are common in north-central Wisconsin, but, excluding one individual that was caught in Manitowish Lake, the nearest other records of this species are hundreds of kilometers to the south and west of the

Table 1. Fish species reported as present from selected areas of the Trout River drainage basin. See Text for sources of data. A "?" indicates that the species is reported or suspected to be present, but is not confirmed.

Common Name	*Scientific Name*	*Manitowish Lake*	*Trout River*	*Trout Lake*	*Trout Lake Tributaries*
SALMONIDAE					
Cisco	*Coregonus artedii*	X		X	
Lake Whitefish	*C. clupeaformis*			X	
Brook Trout	*Salvelinus fontinalis*				X
Lake Trout	*S. namaycush*			X	
ESOCIDAE					
Grass Pickeral	*Esox americanus*	X[1]			
Northern Pike	*E. lucius*	X	X	X	X
Muskellunge	*E. masquinongy*	X	?	X	
UMBRIDAE					
Central Mudminnow	*Umbra limi*		X		X
CYPRINIDAE					
Brassy Minnow	*Hybognathus hankinsoni*		X		X
Hornyhead Chub	*Nocomis biguttatus*		X	X[1]	X
Golden Shiner	*Notemigonus crysoleucas*	X	X	X	X
Pugnose Shiner	*Notropus anogenus*	X[1]	X		
Common Shiner	*N. cornutus*	X	X	X	X
Blackchin Shiner	*N. heterodon*	X	X	X	X
Blacknose Shiner	*N. heterolepis*	X	X	X	X
Spottail Shiner	*N. hudsonius*	X			
Rosyface Shiner	*N. rubellus*	X	X	X[2]	X
Mimic Shiner	*N. volucellus*	X	X	X	X
Northern Redbelly Dace	*Phoxinus eos*				X
Finescale Dace	*P. neogaeus*				X
Bluntnose Minnow	*Pimephales notatus*	X	X	X	X
Fathead Minnow	*P. promelas*		X		X

Table 1. (Continued)

Common Name	Scientific Name	*Manitowish Lake*	*Trout River*	*Trout Lake*	*Trout Lake Tributaries*
CYPRINIDAE (Continued)					
Blacknose Dace	*Rhinichthys atratulus*				X
Creek Chub	*Semotilus atromaculatus*		X		X
Pearl Dace	*S. margarita*		X		X
CATOSTOMIDAE					
White Sucker	*Catostomus commersoni*	X	X	X	X
Silver Redhorse	*Moxostoma anisurum*	X	?	?	
Golden Redhorse	*M. erythrurum*		?	?	
Shorthead Redhorse	*M. macrolepidotum*	X	X	X	
Greater Redhorse	*M. valenciennesi*		X	X	
ICTALURIDAE					
Black Bullhead	*Ictalurus melas*	X	X	X	X
Yellow Bullhead	*I. natalis*	X	X		
PERCOPSIDAE					
Troutperch	*Percopsis omiscomaycus*			X	
GADIDAE					
Burbot	*Lota lota*	?	X	X	?
CYPRINIDONTIDAE					
Banded Killifish	*Fundulus diaphanus*		X		X
GASTEROSTEIDAE					
Brook Stickleback	*Culaea inconstans*		X	X	X
Ninespine Stickleback	*Pungitius pungitius*			X	
CENTRARCHIDAE					
Rock Bass	*Ambloplites rupestris*	X	X	X	X
Pumpkinseed	*Lepomis gibbosus*	X	X	X	X
Bluegill	*L. macrochirus*	X	X	X	X
Northern Longear Sunfish	*L. megalotis pelastes*	X[1]	X		
Smallmouth Bass	*Micropetrus dolomieui*	X	X	X	
Largemouth Bass	*M. salmoides*	X	X	X	X
Black Crappie	*Pomoxis nigromaculatus*	X	?	X	
PERCIDAE					
Iowa Darter	*Etheostoma exile*	?	X	X	X
Fantail Darter	*E. flabellare*		X	X	
Least Darter	*E. microperca*	?	X		
Johnny Darter	*E. nigrum*	X	X	X	
Yellow Perch	*Perca flavescens*	X	X	X	X
Logperch	*Percina caprodes*	X	X	X	X
Walleye	*Stizostedion vitreum*	X	?	X	
COTTIDAE					
Mottled Sculpin	*Cottus bairdi*		X	X	X
Slimy Sculpin	*C. cognatus*			X	
TOTAL (confirmed species)		29	36	35	30

[1] = only a few captured; self-sustaining population probably not present.

[2] = the WDNR Fish Distribution Survey Database also reports Emerald Shiners *(Notropis atherinoides)* from Trout Lake, but I believe that this report is based on misidentified rosyface shiners.

Trout River (Becker 1983; WDNR Fish Distribution Survey Database).

The greater redhorse is also on the watch list in Wisconsin (Les 1979). This species is found in the north-central and northeastern United States and southern Canada, and like the pugnose shiner, is nowhere particularly common (Jenkins 1980). The greater redhorse occurs mainly in small to medium-sized warm-water rivers. While these types of rivers are common in north-central Wisconsin, the nearest other records of this species, excluding Trout Lake (Greene 1935; personal observations), are hundreds of kilometers to the south and west of the

Table 2. Relative abundance of fish species in four stretches of the Trout River. C = common or abundant; P = present in moderate numbers; U = uncommon or rare; ? = suspected or reported as present, but no specimens were observed or captured.

	Stretch			
Species	*Highway 51*	*Golf Course*	*Campsite*	*Logging Road*
Northern Pike	P	P	P	?
Muskellunge		?		?
Central Mudminnow			P	P
Brassy Minnow			U	U
Hornyhead Chub	C	C	C	C
Golden Shiner		?		U
Pugnose Shiner			P	P
Common Shiner	C	C	C	C
Blackchin Shiner		?	P	P
Blacknose Shiner		?	C	C
Rosyface Shiner	U	P	P	U
Mimic Shiner	C	C	U	
Bluntnose Minnow	C	C	P	P
Fathead Minnow			U	U
Creek Chub	C	?	P	P
Pearl Dace			U	U
White Sucker	P	?	U	U
Silver Redhorse	?	?		
Golden Redhorse	?	?		
Shorthead Redhorse	U	C		
Greater Redhorse	?	C		
Black Bullhead	U		U	
Yellow Bullhead				U
Burbot				U
Banded Killifish			U	U
Brook Stickleback	U		U	
Rock Bass	C	?	C	P
Pumpkinseed		?	P	
Bluegill			C	P
Northern Longear Sunfish			C	P
Smallmouth Bass	P	?	U	?
Largemouth Bass	U	?	U	?
Black Crappie		?		
Iowa Darter	C	?	U	C
Fantail Darter		P		
Least Darter		P	C	C
Johnny Darter	P	P	P	P
Yellow Perch	P	P	C	P
Logperch	C	P	C	P
Walleye	?	?	?	?
Mottled Sculpin	C	P		
TOTAL (confirmed species)	19	14	29	25

Trout River (Becker 1983; WDNR Fish Distribution Survey Database).

The least darter is also on the watch list in Wisconsin (Les 1979). This species is found in the north-central United States and southern Canada and is fairly common in parts of Michigan (Burr 1980). The least darter occurs in small to medium-sized, clear, weedy streams, and again, while this is a common habitat in north-central Wisconsin, the nearest records of this species are hundreds of kilometers to the south and west of the Trout River (Becker 1983; WDNR Fish Distribution Survey Database).

The northern longear sunfish is threatened in Wisconsin, which means that this species may become endangered and ultimately extirpated if existing populations are not protected (Les 1979). This species is common throughout the central and south-central United States, and the northern edge of the main body of its range is in southeastern Wisconsin (Bauer 1980, Becker 1983). However, isolated populations exist (or formerly existed) in northwestern and northeastern Wisconsin, central Minnesota, northern Michigan, and southern Ontario; the Trout River population can be added to this list of isolated populations. The northern longear sunfish typically occurs in clear, medium-sized streams or small rivers, which are common in north-central Wisconsin, but the nearest populations of this species are 200 kilometers to the east and west of the Trout River (Becker 1983; WDNR Fish Distribution Survey Database). One northern longear sunfish and one northern longear X unknown sunfish hybrid were captured from Manitowish Lake during extensive sampling of the lake in the early 1980s (Harland Carlson, WDNR-Woodruff, personal communication).

Two species that reach the edge of their range and are rare in north-central Wisconsin, the banded killifish and the fantail darter, occur in low numbers in the Trout River. Both species are common in southern Wisconsin (Becker 1983). The fantail darter is also found in low numbers in Trout Lake, whereas the banded killifish is found in low numbers in Stevensons and Mann Creeks, two tributaries of Trout Lake (Greene 1935; WDNR Fish Distribution Survey Database; personal observations).

Discussion

The Trout River contains a diverse assemblage of fishes. This diversity probably results, at least in part, from two factors, the essentially pristine condition of the river, and the wide variety of habitat present. Excluding a minimal amount of runoff from the golf course and logging operations in the watershed, the Trout River is not adversely affected by human activities. Fish species richness in streams generally declines with increasing environmental degradation (Karr 1981). Fish species richness in streams is usually high in areas with diverse habitat (Gorman and Karr 1978), particularly when cover and large woody debris are common (Angermeier and Karr 1984). The Trout River contains a wide range of habitat types, and macrophytes, boulders, and large woody debris are common in many areas. The Trout River also has an unusual combination of both high, medium, and low gradient stretches; diversity of gradient is directly related to fish species distribution and richness in streams (Burton and Odum 1945, Hocutt and Stauffer 1975).

The species richness of the Trout River is probably higher than my sampling indicated. WDNR surveys during the early 1960s reported muskellunge and walleye from the river below the County Highway H bridge. These two species probably occur in small numbers in the stretches that I sampled; my sampling gears were not particularly effective for large gamefish. Golden and silver redhorse have been reported (Harland Carlson, WDNR-Woodruff, personal communication) but not confirmed from Trout Lake, and silver redhorse are present in the Manitowish River and Manitowish Lake (WDNR Fish Distribution Survey specimens). I have observed large aggregations of spawning redhorse in the Trout River in the spring, and I would not be surprised if these aggregations contained silver and possibly golden redhorse. A troutperch was captured at the outlet of Trout Lake in 1908 (UWZM specimen), and this species, which is common in Trout Lake, may occasionally enter the river. During the early 1980s, a lake whitefish used the Trout River to travel between Trout Lake and Little Star Lake (Lyons 1984). Black crappie may also enter the river from Trout or Manitowish Lakes.

The Trout River contains several species that, excluding other waters in the Trout River drainage, have not otherwise been reported from within at least 200 kilometers of Vilas County. Yet many drainages in north-central Wisconsin besides the Trout River appear to contain habitat suitable for at least some of these species. This suggests that the Trout River drainage may be an unusual environment, with some combination of characteristics that does not exist elsewhere in the region. Conversely, the absence of records of these species from outside the Trout River drainage may reflect the lack of sampling of warm-water streams and rivers in north-central Wisconsin, rather than a true absence of these species.

Management Recommendations

The Trout River currently has very little fishing pressure. During all my sampling I saw only three groups of anglers and one group of bait minnow collectors. Clearly the river can support greater fishing pressure. Large panfish are common in the river. Although relatively few large gamefish occupy the river, those present add diversity to angling opportunities on the river and give the angler at least a chance of catching a large fish.

One of the reasons for the low fishing pressure on the Trout River is a lack of access. The only easy public access points in the 7.5 km area that I sampled are the Highway 51 and the logging road bridges. The easiest and probably most popular way to fish the river is from a canoe, floating the river between these two bridges. Fishing float trips on the river are particularly enjoyable because the absence of human habitations or people along the shore gives the river a "wilderness" quality that is all too rare in most parts of Wisconsin. Thus, I suggest that efforts to increase angling on the river focus on encouraging more fishing from canoes, rather than increasing the number of access points.

Given the species-rich fish assemblage and the rare species present, I recommend that the Trout River be managed primarily for preservation of the existing fish assemblage, and only secondarily for fishing. It would be a tragedy if some of the rare fish in the river were eliminated because of a poorly conceived fish stocking or habitat modification designed to improve fishing.

Although much of the river's watershed is state forest land, lumbering in the riparian zone or along tributaries is a potential threat to the continued integrity of the Trout River ecosystem. To protect the fish fauna and undegraded character of the river, I recommend that the portion of the river that I sampled be considered for inclusion in the Wisconsin Natural Areas Program. If designated as a Natural Area, the Trout River would be protected from most sources of environmental damage and would be likely to retain its current fish assemblage for many years to come.

Acknowledgments

I thank Phil Cochran, Louis Doelp, Tim Draissic, Mike Jech, Barry Johnson, Vincent Lyons, Greg Marron, John Osborne, and Dan Schneider for help with sampling. I also thank Harland Carlson for providing information on fish sampling in Manitowish and Trout Lakes, and Don Fago for showing me how to access the WDNR Fish Distribution Survey Database. Cheryle Hughes drew the figure. Support for field work came from the Center for Limnology and the University of Wisconsin Zoological Museum. This report was financed in part by the Federal Aid in Fish Restoration Act under Dingell-Johnson Project F-83-R, Study 501.

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Lightning and the Enlightenment: An Essay on Lightning by G. C. Lichtenberg

Ralph C. Buechler

After Benjamin Franklin had installed a lightning rod on his Philadelphia home in 1749 and performed his legendary kite-flying experiment in 1752, European scientists like Priestly in England, Volta in Italy, and Lichtenberg in Germany soon joined him in the exploration of the nature of electricity.

Probably the least known of these, Georg Christoph Lichtenberg was Professor for Experimental Physics at the newly founded Hanoverian University of Göttingen. This discussion will deal with Lichtenberg's work *Über Gewitterfurcht und Blitzableitung (On Lightning Rods and the Fear of Lightning),* written in 1795 after Lichtenberg became the first citizen of Göttingen to attach a lightning rod to his home.

Lichtenberg understands the fear of thunder and lightning and the imagination underlying it and suggests an enlightened response to these natural phenomena based upon a knowledge of nature (science) and a practical solution to nature (here, the lightning rod). "Tell him," Lichtenberg advises in regard to the uninformed person who trembles at each peal of thunder and flash of lightning, "that lightning, whose thunder shakes the ground, may be led through a bit of wire or a little metal covering to wherever one might want it."[1]

Prior to the latter half of the seventeenth century the nature of electricity was as mysterious as its application. Indeed, observations on electricity were limited to lightning storms on the one hand and to curiosity about the peculiar forces of attraction demonstrated by such minerals as amber and lodestone on the other.

But during the eighteenth century, the understanding of electricity was advanced beyond hearsay, ignorance, and mere conjecture. In 1660 Otto von Guericke of Magdeburg constructed the first primitive electro-static generator; in 1729 Stephen Gray discovered the principle of conduction; and in 1745 Ewald G. Kleist and Pieter van Musschenbroeck independently fashioned the Leyden jar, the first electrical condenser to store an electrical charge.

By the middle of the eighteenth century interest in lightning had taken a central position amidst all this generating, conducting, and storing of static electricity. Once mythified as the thunderbolt of Zeus and Jupiter or as the wrath of God, lightning was now observed to have properties that appeared to be similar to those noted during experimentation with static electricity.

Deducing from his own experiments with static electricity and the Leyden jar,[2] Benjamin Franklin hypothesized as early as 1749 the relationship between electricity and lightning. He subsequently tested his hypothesis in the famous kite experiment of 1752.[3] But even prior to his experiment Franklin had suggested that a sharp metal rod pointed skyward and connected to the ground would attract charges of electricity and lead them into the ground, keeping them away from buildings.[4]

It proved to be of inestimable importance to the European scientific com-

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munity that Franklin wrote of his findings in clear and detailed letters to a certain Peter Collinson, London merchant and member of the Royal Society. These letters were published in the Society's *Transactions,* and Franklin himself was made a fellow of the Society in 1756.

Just two years later Johann Carl Wilcke of Wismar translated Franklin's *Experiments and Observations on Electricity* into German.[5] A dozen years later still, in Göttingen, where Wilcke himself had studied from 1753–1755, Lichtenberg was named professor of experimental physics. In the capacity of researcher and teacher, he studied and repeated the experiments of Franklin and the leading European electro-physicists.

Lichtenberg broke no new ground with his experiments and reflections on electricity; he repeated and varied the work of others before him[6] primarily for self-edification and, most importantly, for his classes at the university.

Lichtenberg's essay *On Lightning Rods and the Fear of Lightning* is not an objective, verifiable, and exhaustive treatment or treatise contributing new knowledge. Why, then, did Lichtenberg write it?

Lichtenberg writes of lightning from the standpoint of the scientist, the philosopher, and the individual who is fascinated and awed by thunderstorms. He collected accounts of storms from his friends and colleagues as avidly as others might collect stamps or coins. He writes in a July 1783 letter: "The news of your thunderstorms was for me as entertaining as it was terrible. I always receive such news with gratitude, especially the exact description of the route taken by the lightning near buildings and other large, physical bodies."[7]

Lichtenberg does not deny the subjective and aesthetic experience of nature. His own notes and the memoirs of his students are replete with his personal, often nervous, responses toward the approach of a storm. In his letters he writes enthusiastically of the sublime nature of thunder and lightning; they both repel and attract him. Thus Lichtenberg remarks in the letter of July 1783 that "my body is, as it should be for the body of a physics professor, a never-failing barometer, thermometer, hygrometer, manometer, etc."[8] Still more revealing is a letter to his friend Franz Ferdinand Wolff on 21 July 1783:

> Just now the first rays of sunshine have appeared after a fearfully beautiful thunderstorm with hail, which has just passed and of which the roofs are still dripping. I was not a little concerned about our town. As the storm arose, it turned almost dark and every flash of lightning struck home. . . . The day had been unbearably hot and I was unusually sensitive, on top of which it is the anniversary of my father's death. Nothing in the world could resemble more my state of mind than such weather. Once, as it thundered deeply, I thought it was directly under me, so I can truly say, I've never felt my mortality more than at that moment. Indeed, tears came to my eyes out of amazement. Surely, there is nothing more grand or majestic.[9]

Lichtenberg attempts from the outset of his essay to demonstrate the unreasonableness of the fear of lightning by developing an analogy between stormy weather and disease. Between the unstable conditions of the atmosphere and the human body, the potential of danger and suffering operates as the point of comparison. Lichtenberg even collapses the two into one metaphor, speaking, for example, of "smallpox weather" or of clothing as "dysentery rods." He begins:

> As I write this (at the beginning of August, 1794) one may note in our vicinity as in others, evidence of dysentery. Already six people are said to have perished; that would be twice as many in a few days as lightning has killed in our city in the last half century; and how many people has dysentery probably killed in that half century? But no one

> seems upset by that. I see that one hardly bothers with the simplest "dysentery rods."[10]

Lichtenberg responds to this unreasonable disparity between perceived and actual danger with an understatement: "Isn't that curious?"

But Lichtenberg does more than identify the human reaction to thunderstorms. He offers three different antidotes: the use of imagination, the use of reason, and the implementation of a practical solution—the lightning rod.

As to the first, if brontophobia (the fear of thunder) is largely the result of an over-active imagination, Lichtenberg suggests employing that same faculty in conjuring up images of true danger, such as a battlefield, so that one may become aware of the ridiculous nature of such irrational fears. He prescribes laughter as an antidote. Recounting an actual case in which a man subject to extreme fear of thunder tried this "antidote," Lichtenberg remarks: "I know that this strategey was so effective, that, while the thunder rolled and the rain beat like hail against the window, the patient himself began to smile at his own fears, due to the obvious contrast."[11]

Second, Lichtenberg identifies the roots of brontophobia in childhood from the use of fear as an instrument of discipline. More dominant still is the power of sound, causing us to misplace our fear in thunder, not lightning. Thus Lichtenberg muses: "I'd really like to know, if anyone has ever heard of someone deaf who is fearful of a thunderstorm."[12] Here he proposes the simple truth as a route out of naivety, prejudice, and ignorance:

> Against this fear—planted by improper upbringing and supported by human nature—I know no other advice than that one instruct the patient in the truth, pure and simple. Explain to him what lightning is without understatement or exaggeration. Compare the dangers of lightning to that of diseases, and demonstrate that thunderstorms are the gentlest of diseases that can befall a city. More persons die of heart attacks in every city in one year than of lightning throughout the whole country in ten years.[13]

On a third level Lichtenberg's attempts at enlightenment reach a practical fulfillment—the use of the lightning rod:

> But now, if it were in our power, perhaps not to destroy, but to control this lightning which frightens us so when accompanied by a barrage of thunder, to protect ourselves from it as we do from the rain? We can, and with the same certainty with which we escape from the rain under a good roof or the sun under a thick shade tree.[14]

Comparing lightning to the cold, Lichtenberg notes the similarity between lightning rods and fuel or clothing. In either case, failure to avail oneself of these protective instruments may result in dire consequences. "Extreme cold is much more horrible and dangerous than all the thunderstorms of six summers together, although the latter causes a great deal more commotion. But is one not afraid of the cold? Because we have proven 'cold rods' against it, namely, fuel and clothing."[15]

Although he does refer to some aspects of the correct installation of a lightning rod,[16] Lichtenberg states outright that "our purpose here is not to give a lesson in proper lightning rod installation." Ostensibly a discussion on lightning and lightning rods, Lichtenberg's essay is really a dialogue between writer and reader on ignorance, superstition, truth, and knowledge. The topic is the nature of lightning, but the theme is human nature.

Lichtenberg's essay seeks to fulfill three major didactic functions. On a psychological level it speaks of the irrationality of human phobias toward lightning by speaking of the truths garnered from the connection established between lightning and electricity. On an aesthetic level he seeks to replace this fear of lightning with the experience of the sublime effect of storms—one can hardly enjoy a good storm if one is afraid of it. Lastly, he speaks of the social welfare that accrues through peace of mind and actual property protection from the construction of lightning rods.

In conclusion, an eighteenth-century German essay on electricity and lightning ultimately proves to be of great value to the general reading public of his time. Lichtenberg's essay functions as a literary lightning rod that serves as an instrument to control, channel, and ground superstition and unreason.

Notes

[1] Georg Christoph Lichtenberg, "Über Gewitterfurcht und Blitzableitung," in *Aufsätze gelehrten und gemeinnützigen Inhalts,* Vol. III of his *Schriften und Briefe,* ed. Wolfgang Promies (München: Carl Hauser Verlag, 1972), p. 133. All subsequent citations of Lichtenberg's essay are taken from this source.

[2] Franklin proposed correctly that, in contrast to the two-fluid theory of Dufay and others, electricity must be understood as a single "fluid" that may be positively charged.

[3] Acting upon Franklin's suggestions, the French scientist D'Alibard charged an electric bottle from a flash of lightning, thus demonstrating the identity of electricity and lightning.

[4] Franklin included a detailed account of the construction and function of the lightning rod in his *Poor Richard's Almanac* of 1753.

[5] See Benjamin Franklin, *Des Herrn Benjamin Franklins Briefe von der Elektrizität,* trans. Carl Wilcke, eds. Roman Sexl and Karl von Meyenn (Braunschweig: Edition Vieweg, 1983).

[6] Lichtenberg's discovery of his "Lichtenberg Figures"—snowflake-like structures of dust on the surface of an electrophor caused by static electrical discharge—represents a minor exception.

[7] "To Gottfried Hieronymous Amelung," 3 July 1783, Letter 398, in *Briefe,* Vol. IV of his *Schriften und Briefe,* ed Wolfgang Promies (München: Carl Hauser Verlag, 1972), p. 515. All subsequent citations of Lichtenberg's letters are taken from this source.

[8] "To Gottfried Hieronymous Amelung," 3 July 1783, Letter 398 in *Briefe,* p. 515.

[9] "To Franz Ferdinand Wolff," 21 July 1783, Letter 402 in *Briefe,* p. 519.

[10] Lichtenberg, "Über Gewitterfurcht und Blitzableitung," p. 130.

[11] Lichtenberg, "Über Gewitterfurcht und Blitzableitung," p. 132.

[12] Lichtenberg, "Über Gewitterfurcht und Blitzableitung," p. 133.

[13] Lichtenberg, "Über Gewitterfurcht und Blitzableitung," p. 133.

[14] Lichtenberg, "Über Gewitterfurcht und Blitzableitung," p. 134.

[15] Lichtenberg, "Über Gewetterfurcht und Blitzableitung," p. 135.

[16] Lichtenberg, was among the first to insist that grounding the lightning rod is the most essential component of proper lightning rod installation.

Land Use and Vegetational Change on the Aldo Leopold Memorial Reserve

Konrad Liegel

Abstract. *This study records land use and vegetational changes on the Aldo Leopold Memorial Reserve in Sauk County, Wisconsin. Vegetation maps were prepared for the early European settlement (1840s) and early Leopold (1930s) eras through interpretation of surveyor's notes, traveller's accounts, soils information, aerial photographs, agricultural records, present vegetation, and on-site observations. These maps, compared with each other and with the present vegetation map (1978, rev. 1986), show trends in vegetational change since the time of settlement. Closed communities of shrub-carr and forest have replaced open communities of low prairie, sedge meadow, and oak savanna. The primary factor responsible for this change is the control of fire.*

Land-use records indicate that agricultural use helped to delay this succession of communities. Grazing kept the savannas open although it destroyed the natural groundlayer. Therefore, in 1940 more prairie species remained in the minimally grazed black oak forests than in the heavily grazed white oak savannas. The mowing of marsh hay, meanwhile, kept the wet prairie and sedge meadow open. When grazing and mowing stopped, shrubs and trees quickly invaded. Agricultural use peaked in the 1920s, but declined in the 1930s through the 1960s due to meager natural soil fertility, the introduction of modern mechanized farming, and farmer attrition.

The plant communities of southern Wisconsin have changed dramatically in the years since glaciation. European settlement and subsequent land use, in particular, thoroughly modified the plant communities, primarily through the control of fires that resulted from lightning strikes and Indian activities (Dorney 1981). In the absence of fire, the sunny oak openings of southern Wisconsin grew up into the oak woodlots of today, while shrub-carr and aspen invaded the sedge meadows and low prairies. Lumbering and farming transformed most of the remaining expanses of prairie, savanna, marsh, and forest into today's fields of corn and hay (Curtis 1959).

This study records the changes in land use and vegetation on what is now the Aldo Leopold Memorial Reserve. The Reserve is the "sand country" of Aldo Leopold, where he and his family spent their weekends and vacations in the 1930s and 1940s restoring a worn-out farm north of Baraboo, Wisconsin. Leopold studied the land-use and ecological history of his farm searching for guidance on how to restore it to a healthy state. Leopold's experiences at the farm also helped in shaping his philosophy of man's relationship to his environment—the land ethic—which is expressed in *A Sand County Almanac* (1949):

> Conservation is getting nowhere because it is incompatible with our Abrahamic concept of land. We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. There is no other way for land to survive the impact of mechanized man, nor for us to reap from it the esthetic harvest it is capable, under science, of contributing to culture.

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It seems fitting, therefore, that the ecological story of the Leopold farm and the Reserve surrounding it be told. This land-use and vegetational history illustrates a principle implicit in the writings of Leopold: the pattern and composition of vegetational communities reflect the choices human cultures have made in land use.

Description of the Leopold Memorial Reserve

The Aldo Leopold Memorial Reserve is a private landowner's cooperative tract of approximately 1400 acres dedicated to the memory of Aldo Leopold. Among other properties, it contains Leopold's original farm, which includes "the Shack," now listed in the National Register of Historic Places. A refurbished chicken coop, later memorialized in *A Sand County Almanac,* the Shack was home to the Leopold family during visits to their farm. The Reserve is located in Fairfield Township, Sauk County, Wisconsin (R7E, T12N, Sec. 2, 3, 4, 5; R7E, T13N, Sec. 32, 33, 34, 35) (Fig. 1) where the Wisconsin River and its floodplain cut a swath through the ground moraine with its wetlands left by the last ice sheet.

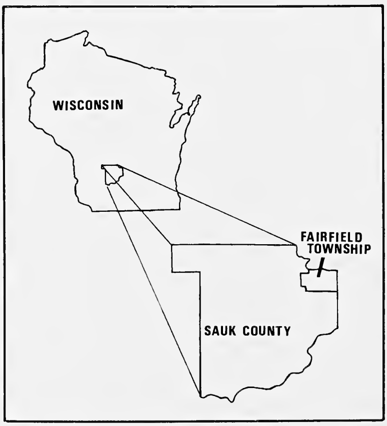


Fig. 1. Location of the Aldo Leopold Memorial Reserve, Sauk County, Wisconsin.

Glaciation, subsequent wind erosion, and the fluvial action of the Wisconsin River have molded the Reserve's surface features (Fig. 2). The Reserve is covered with a mantle of supraglacial sediments and till laid down by a series of glacial advances, the last being the Green Bay Lobe of late Woodfordian age (Black and Rubin 1967–1968), which reached its maximum advance into the area about 13,000 years ago (Socha 1984). As the glacier melted, an extension of Glacial Lake Wisconsin formed to the east of the terminal moraine, covering the Reserve. The north-south-trending ridges in the Reserve area were probably fashioned during this time as deltas in the lake at the ice margin. The proglacial lake existed in the Reserve area until the ice margin cleared the east end of the Baraboo range and uncovered a low area near Portage. The proglacial lake drained through this outlet, establishing the present course of the Wisconsin River. Subsequently, the river eroded the north end of the sand and gravel ridges. Eolian processes reworked both the proglacial fluvial and modern fluvial deposits and formed blowouts and dunes, leaving the topography of today (Socha 1984).

Fire stress, fluctuating water levels, and siltation levels have determined the changing pattern and composition of plant communities on the Reserve (Liegel 1982). Presently, about two-thirds of the area is floodplain forest and marshland, dotted with ponds and laced with river sloughs. The remainder is hilly ground moraine covered by a mixed oak-hickory-pine forest and broken by a few fields still under cultivation (Luthin 1980; Bradley 1987). A deep, sandy substrate underlays the entire Reserve and produces an easily eroded soil of low fertility (Sharp and Bowles 1985).

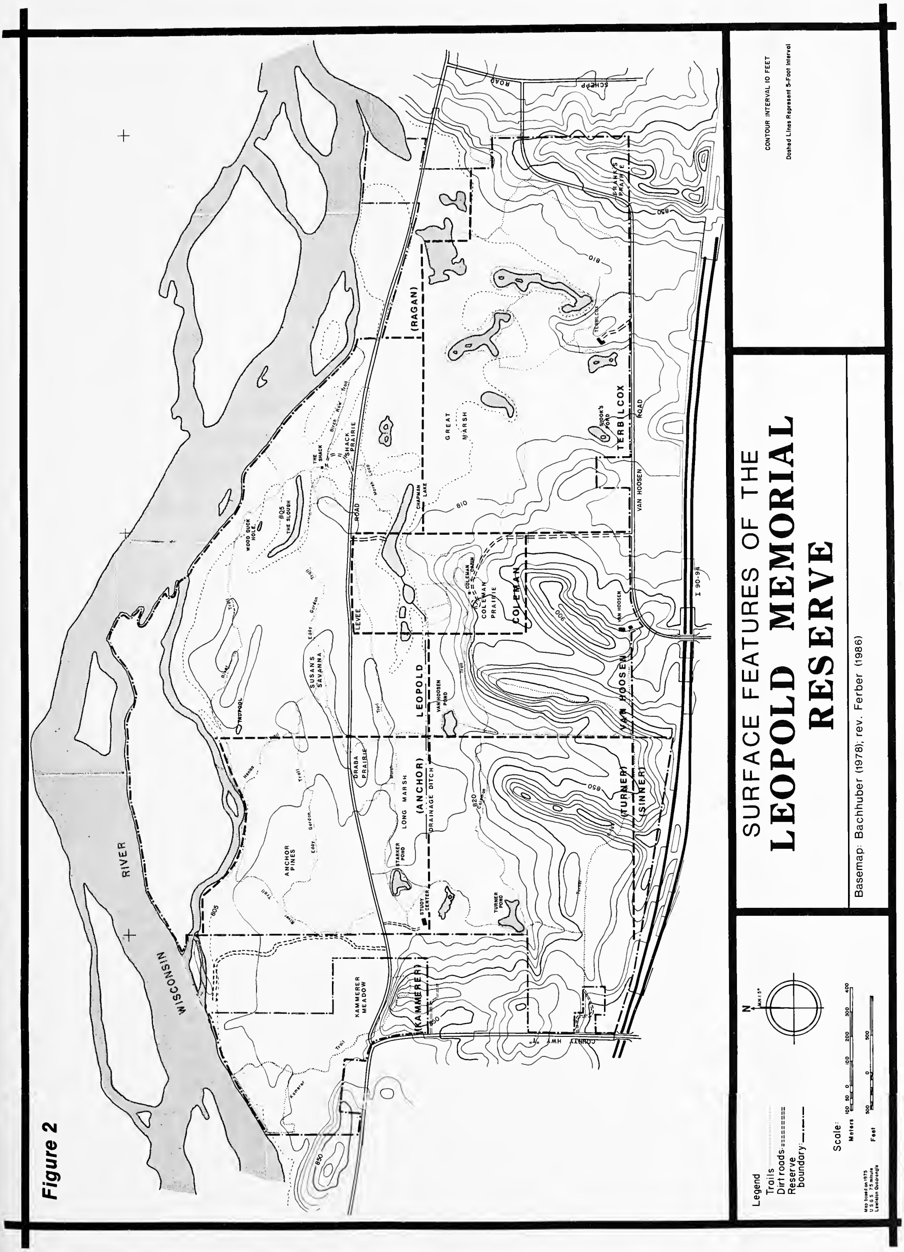

SURFACE FEATURES OF THE
LEOPOLD MEMORIAL
RESERVE
Basemap: Bachhuber (1978); rev. Ferber (1986)
CONTOUR INTERVAL 10 FEET
Dashed Lines Represent 5-Foot Interval
Legend
Trails
Dirt roads
Reserve boundary
Scale:
Meters
Feet
N
WISCONSIN
RIVER
KAMMERER MEADOW
(KAMMERER)
ANCHOR PINES
STUDY CENTER
STARKER POND
TURNER POND
LONG MARSH
(ANCHOR)
DRAINAGE DITCH
DRABA PRAIRIE
TADPOLE
SUSAN'S SAVANNA
LEOPOLD
VANHOOSEN POND
LEVEE
WOOD DUCK HOLE
THE SLOUGH
COLEMAN PRAIRIE
COLEMAN
(TURNER)
(SINNER)
VAN HOOSEN
I 90-94
CHAPMAN LAKE
THE SHACK
SHACK PRAIRIE
GREAT MARSH
(RAGAN)
TERBILCOX
VAN HOOSEN ROAD
FRANK'S PRAIRIE
SCHEPP ROAD
COUNTY HWY T
805
810
820
850
900

Figure 2

European immigrants settled the area in the 1840s. At that time oak savanna maintained by fires was the dominant ecotype (Liegel 1982). Lumbering, cultivation, drainage of wetlands, overgrazing, mowing, and fire suppression caused rapid changes in the vegetative cover. Farming reached its zenith in the mid-1920s, with farms being abandoned to brush and weeds, wind and weather during the drought and depression of the 1930s. In 1935 Aldo Leopold purchased one of these abandoned farms and started to reverse the process of land deterioration through management and restoration, an activity that continues today under the direction of Frank Terbilcox, Manager, and Charles and Nina Bradley, Co-Directors of Research of the Leopold Memorial Reserve, and through the financial support of the Sand County foundation.

Methods

I based this study of vegetational change on a land-use chronology of the Leopold Memorial Reserve and on a series of vegetation maps of the Reserve during the 1840s (Liegel 1982), 1930s, and 1970s (Luthin 1978, rev. Ferber 1986). Land-use chronologies are an effective tool for generating hypotheses as to the relation between past land-use actions and present ecological effects, for broadly illustrating the significant impact humankind has had on the environment, and for helping to make management decisions (Leopold 1940; Grange 1948; Leopold 1949; Scott 1980). A comparison of vegetation maps for different time periods of the same piece of land, meanwhile, graphically and quantitatively shows the precise changes in percentage land cover by different plant community types over time (Curtis 1959; Vogl 1964).

Land-Use Chronology

This land-use chronology is based on historical documents that covered events within a larger area than the Reserve itself, namely that portion of Wisconsin surrounding the Wisconsin River between Wisconsin Dells and Portage. The historical documents considered include the following: state histories (Smith 1854; Nesbit 1973; Smith 1973; Current 1976); regional histories (Gregory 1932), county histories (Canfield 1861a; Butterfield 1880a and 1880b; Jones 1914; Cole 1918; Lange 1976); the published accounts of early explorers (including Carver [1766] 1838; Nuttall [1810] 1951; Schoolcraft [1820] 1953; Featherstonaugh 1847), pioneers (including Childs 1859; Kinzie 1856), and lumbermen (including Babington 1928); newspaper articles (Baraboo and Portage); and the journals of Reserve inhabitants Melvin Felt (1879–1899), Aldo Leopold (1935–1948), and Charles Bradley (1978–1987).

Written descriptions have their limitations for reconstructing past landscape and land-use patterns. Such historical descriptions are frequently vague, occasionally biased, and almost always very general (Vale 1982). However, for some time periods, especially prior to 1840, they are the only resource a land historian has to reconstruct past vegetation.

Finally, the chronology is based on the 1860–1900 Agricultural Census Schedules for Wisconsin of the U.S. Department of Agriculture (the records for 1910 and 1920 were destroyed in a fire) and the 1923–1972 Annual Enumeration of Farm Statistics by Assessors of the Wisconsin Department of Agriculture, both found in the Archives of the State Historical Society of Wisconsin. The agricultural schedules record, by individual farmer and county, the following statistics: amount of land owned; acreage devoted to various crops, pasture land, marsh hay, woodland, and unplowed land; numbers and kinds of livestock; and use of electricity, centralized heating, tractors, and fertilizers.

Agricultural census records likewise

have their limitations for reconstructing past agricultural-use patterns. Census figures often were conservative estimates from the farmers (Statz 1982, pers. comm.), and occasionally they appeared somewhat incomplete or inconsistent. To minimize these problems, the census figures were closely compared with the other historical documents.

In order to use the records, the land ownership history of the Reserve was determined through a search in the Sauk County Register of Deeds and in individual abstracts for particular properties. Then the agricultural records for each property were tabulated by individual landowner and year. Finally, by comparing the agricultural records with each other, and with the journals of Reserve inhabitants, field observations of the various fence lines, aerial photographs (1937; 1940; 1955; 1968), and various plat maps of Fairfield Township (Canfield 1861b; Tucker 1877; 1906; 1920; 1936; 1947; early 1950s; 1961; 1972; 1976), I was able to determine approximately when individual parcels were cultivated, mowed, or grazed, and for how long.

Vegetation Maps

Vegetation maps were prepared for the early European settlement (early 1840s) and early Leopold (late 1930s) eras of the Leopold Reserve for comparison with each other and with the present vegetation map (1978, rev. 1986) to show trends in vegetational change since the time of settlement. These periods were chosen because of their special importance to understanding the ecological history of the Reserve and because of the availability of survey information and/or aerial photographs for making a map of the vegetation during that period. The plant community types were delineated to follow those described by Curtis (1959).

A detailed description of the methods used in preparing the map of the early European settlement vegetation of the Reserve can be found in Liegel (1982).

The vegetation map of the Leopold Reserve in the late 1930s was prepared from the 1940 Agricultural Stabilization and Conservation Service (ASCS) aerial photograph. Community types and boundaries were derived from the following sources used in conjunction with the 1940 ASCS aerial photograph:

1. The Bordner Land Economic Inventory (1938) for Sauk County, the data originally recorded by field workers who traversed each quarter mile of land, noting both vegetational communities and human land use;
2. The ASCS aerial photograph of 1937;
3. The Shack journals of Aldo Leopold (1935–1948);
4. A herbarium collection of Carl Leopold (1938–1940);
5. Recollections of the Leopold family.

In addition, a stereoscopic wetland mapping procedure, developed by the Wisconsin DNR Wetlands Inventory (Wetlands Mapping Staff 1981), was used to delineate boundaries between different wetland community types that otherwise could not have been delineated on the aerial photographs.

Luthin (1978; 1979; 1980) prepared the present vegetation map through field observations while accompanying a baseline survey of the Reserve. Ferber (1986) revised the vegetation map through comparison with the 1976 infrared and 1978 aerial photographs and through additional field checks. This present vegetation map shows the Reserve boundaries of 1986, whereas the 1840s and 1930s vegetation maps show the Reserve boundaries as of 1980 when the maps were compiled.

The relative area coverage for the different community types was determined by counting dots on a grid placed over each map. The 1980 Reserve boundaries were used in making the calculations so that the relative area coverage for different community types could be quantitatively compared.

Leopold Reserve Chronology

Prehistory (13,000–300 Years Ago)

The Prehistory era was one of great geologic and climatic change, accompanied by a series of changes in vegetation types from the boreal swamp woodlands of the proglacial period to the mosaic of mesophytic forest, oak savanna, and marsh communities found by the earliest European explorers (Maher 1981; Maher 1982; Winkler 1985). The changes in vegetation, in turn, were accompanied by a change from nomadic tribes of Indians to more sedentary tribes (Quimby 1960; Wittry 1979a; Wittry 1979b).

The first documented aboriginal use of the area surrounding and including the Leopold Reserve was by the Effigy Mound culture of the Woodland Indians about 700 to 1200 years ago (Quimby 1960). Although they still lived by hunting and fishing, the Woodland Indians were the first people in the region to use pottery of fired clay, to raise crops, and to erect mounds over their dead or in the shape of effigies. Several Effigy Mound culture mounds were found near or within the Leopold Reserve, including a possible village site southwest of the Terbilcox residence (Stout 1906; Brown 1924) (Fig. 2). Unfortunately, nothing more is now known about the aboriginal land use of the Reserve area during this period.

Exploration Era (1660–1836)

Social upheaval characterized the Exploration Era. The French, the English, and later the Americans fought for control of the region, and Indian tribes displaced one another as European settlers pushed them westward (Smith 1973). Indian tribes exerted an indirect but substantial effect over the composition of plant and animal communities through the use of fire (Day 1953; Martin 1973; Lewis 1980; Dorney 1981). European trappers affected plant community composition to a somewhat lesser, but perhaps still significant, degree through overexploitation of fur-bearing and large game animal species (Cole 1918; Smith 1973).

The Wisconsin River was the principal means of transportation in the study area prior to settlement. Descriptions of the vegetation and animal life along its banks provide the best evidence of ecological conditions during this period.

When the French explorer and first European visitor Father Marquette paddled his canoe up the Fox, across the Portage, and down the Wisconsin River in 1673, he found a wild land with few Indians and much game. He wrote of the Wisconsin River:

> On the bank one sees fertile land, diversified with woods, prairies, and hills. There are oak, walnut, and basswood trees; and another kind, whose branches are armed with long thorns. We saw there neither feathered game nor fish, but many deer, and a large number of elk. (Kellogg 1917)

Soon after Marquette's explorations, French trappers plyed the Fox-Wisconsin route in search of gold, fur, and skins (Smith 1973). The fur trade system, which continued for the next 125 years, altered the relationships between Europeans and Indian tribes by making the Indians dependent upon French-supplied weapons, traps, ammunition, and blankets (Kellogg 1925). The Indians received these supplies on credit, which they paid for by furs.

The cumulative effect of excessive trapping and hunting began to show up in the area around the Reserve soon after the Americans took over the territory after the War of 1812. By this time elk, moose, and beaver were largely eradicated from the region, and deer were significantly decreased in numbers (Cole 1918; Schoolcraft 1953).

The dominant Indian tribe that occupied the area around the Leopold Reserve at the time of the arrival of European explorers was the Winnebago. The Winnebago made their living by farming and hunting and lived in permanent villages. Two of their villages were in Baraboo and Wisconsin Dells. An Indian path from the village in the Dells traversed the Reserve (Brink 1845). The Winnebago used fire to make good pasture for deer, to drive game, to provide for a renewed growth of blueberries and huckleberries, and for communication (Quimby 1960; Peske 1971; Lange 1976; Dorney 1981).

On a journey from Green Bay to St. Louis in 1821, the Green Bay pioneer, Ebenezer Childs, saw "but seven white men in the whole distance, outside the forts" (Childs 1859). Europeans were moving into the area, however, making the local Winnebago Indians restless. To keep the tribe in check, the American government built Fort Winnebago in 1828 near what is now Portage (Prucha 1964). The temporary barracks were constructed of pine logs obtained from an area known as Pine Island about six miles west of Portage (Turner 1898), which was in the close vicinity of the Reserve. In describing the "portage" during a trip through Wisconsin in 1835, the English scientist Featherstonaugh made this prophetic remark:

> [The portage was covered with] tall wild grass, no longer kept cropped by roving buffaloes, which had been driven beyond the Mississippi. . . . It could not be long before the Indians will go the way of the buffalo, and cultivated grasses replace the native one. . . . The scythe of what is called "civilization" is in motion, and everything will fall before it. (Featherstonaugh 1847)

Two years later the Winnebago Indians ceded their land to the United States government, thereby allowing permanent settlement of the region (Gregory 1932).

Pioneer Era (1837–1865)

The Pioneer era was a transitional one, during which the first pioneers settled and began to farm what is now the Leopold Memorial Reserve. These pioneer farmers, mostly native-born Yankees (Canfield 1861a; Cole 1918), allowed their livestock to run at large and placed fences around their cropland (Gregory 1932). Wildfires were common, especially in the springtime (Gregory 1932). The frontier was pushing westward, with thousands of immigrants using an early state road (now Levy Road) that traversed the Reserve following the original Indian path (Cole 1918; Davis 1947). The cutting of the Wisconsin Pinery north of Wisconsin Dells was in full swing, with "almost a constant run" of log rafts down the Wisconsin River from early spring till early fall (*Wisconsin Power Service Commission v. Federal Power Commission,* Transcript of Record, 1944).

At the time of European settlement of the Reserve area in the early 1840s, the vegetation of the Reserve was an open, fire-maintained mosaic of oak savanna (38% by relative area coverage), floodplain forest (33%), marshland (27%), and upland forest (2%) (Table 1).

Traveller, surveyor, and pioneer accounts provide differing pictures of the vegetation of the area. While surveying the Leopold Marsh, John Brink wrote in his field notes: "Land Level wet and sandy (Quick Sand) 3rd Rate—Black & Yellow Oak and not much of that—Marsh bad enough and good for nothing" (Brink 1845). In contrast, a Gazetteer used to attract immigrants to Wisconsin gave the following general description of the area (Hunt 1853):

> The openings, which comprise a large portion of the finest land of the state, owe

Table 1. Relative area coverage of the plant community types in what is now the Leopold Memorial Reserve, Sauk County, Wisconsin, during the 1840s, the 1930s, and the 1970s.

Plant Community Type	*% of total land surface during the 1840s*	*% of total land surface during the 1930s*	*& of total land surface during the 1970s*
Marsh	27	30	23
Aquatic	(1)	(1)	(2)
Emergent Aquatic	(3)	(3)	(2)
Sedge Meadow	(15)	(10)	(7)
Wet Meadow	(0)	(3)	(4)
Low Prairie	(8)	(2)	(0)
Shrub-carr	(0)	(11)	(8)
Floodplain Forest	33	24	26
Mixed F. Forest	(31)	(22)	(24)
Wet F. Forest	(2)	(2)	(2)
Savanna	38	10	6
Oak Opening	(31)	(2)	(0)
Oak Barrens/Dry Meadow	(7)	(8)	(6)
Upland Forest	2	19	34
Mixed Hard. Forest	(1)	(1)	(7)
Dry Upland Forest	(1)	(18)	(27)
Disturbed Areas	0	17	11
Roadsides	(0)	(1)	(1)
Cultivated Fields	(0)	(16)	(10)

their present condition to the action of the annual fires which have kept under all other fast growth, except those varieties of oak which can withstand the sweep of that element.

This annual burning of an exuberant growth of grasses and of underbrush, has been adding, perhaps for ages, to the productive power of the soil, and preparing it for the plough-share.

It is the great fact, nature has thus "cleaned" up Wisconsin to the hand of the settler, and enriched it by yearly burnings, and has at the same time left sufficient timber on the ground for fence and firewood, that explains, in a great measure, the capacity it has exhibited, and is now exhibiting for rapid settlement and early maturity.

There is another fact important to be noticed in this connection. The low level prairie, or natural meadow, of moderate extent, is so generally distributed over the face of the county, that the settler on a fine section of arable land, finds on his own farm, or in his immediate neighborhood, abundant pasturage for his stock in summer, on the open range; and hay for the winter, for the cutting—the bounty of nature supplying his need in this behalf, till the cultivated grasses may be introduced and become sufficient for his use.

In 1843, Amos Anderson, a native of Norway, settled on the western end of the Leopold Reserve, preparing the ground that year for crops that gave him profitable returns in the following year

(Gregory 1932). He was the first settler in Fairfield Township. Although most of the land within the Reserve passed into private hands by the early 1850s, it was not actively farmed but rather was held onto for a year or more, possibly for speculative purposes, and then sold. By 1854, virtually all of the Reserve lands were being actively farmed.

These pioneer farmers only had about 30 acres under the plow, the rest being used as open range for sheep and cattle. The areas put under cultivation included the "Shack" and "Coleman" prairies (Fig. 2). Corn, wheat, and oats were the primary crops, produced in approximately equal quantities. The principal market was the Pinery (Staines 1852).

Wildfires were common during the 1840s and 1850s, especially in the springtime, but diminished thereafter as the area became settled (Gregory 1932). In the early 1860s, after the cessation of wildfires, pines began to germinate in the "Anchor" woods of the floodplain forest (Leopold 1942) (Fig. 2).

Farming Era (1866–1934)

In southcentral Wisconsin, the Farming era began for both man and wildlife as a time of plenty, but ended for both as a time of devastation. Soldiers returning from the Civil War in the late 1860s placed the remaining fertile land under cultivation (Scott 1980). These farmers cultivated the rolling upland savannas, left the ridge savannas to succeed into forest, and burned off the marshlands for mowing of the marsh hay. A 1870 law, forbidding farmers from allowing their livestock to run at large, stopped indiscriminate grazing but intensified grazing in certain areas (Schafer 1922). The resulting mixture of fields, brushlands, and marshlands created excellent conditions for wildlife. Leopold (1934) described it this way:

> The optimum conditions for game came after settlers had begun to farm the surrounding hill country. The settlers burned large openings in the tamaracks and used them as hay meadows. Every farmer who owned a quarter-section in the hills also owned a forty in the marsh, where he repaired every August to cut his hay. In winter, when frost had hardened the marsh, he hauled the hay to his farmstead.
>
> The open haymeadows, separated by stringers of grass, oak, and popple, and by occasional remnants of tamarack, were better crane, duck, and sharptail range than the primeval bogs. The grain and weeds on the farms abutting the marsh acted as feeding stations for prairie chickens, which soon became so abundant as to take a considerable part of any grain left in the fields. These were the golden days of wildlife abundance. Fires burned parts of the marsh every winter, but the water table was so high that the horses had to wear "clogs" at mowing time, hence no fire ever "bit" deep enough to do any lasting harm.

However, by 1890, after all the fertile uplands were under cultivation, farmers made attempts to crop the marshland in dry years. The first results were bountiful beyond reason and agriculture started with a rush. The marshland fertility unfortunately quickly disappeared and an added succession of wet years reduced the farmers to desperation. To rehabilitate these farmers Wisconsin passed the Drainage Law of 1894, which provided an incentive to restore wetlands to agriculture through ditching and draining (Wisconsin Regional Planning Committee 1934). Now during dry years the exposed peat itself began to burn, rendering cultivation impossible (Leopold 1934). In addition, the meager natural fertility of the upland sandy meadows was depleted. By the 1930s many farms were abandoned in the "sand counties" to brush and weeds, wind and weather (Wisconsin Regional Planning Committee 1934).

Farming activity on the Leopold Memorial Reserve closely followed this regional scenario (see Fig. 2 for the locations on the Reserve of the parcels discussed in this section). During the late 1860s and 1870s most of the fertile land, now part of the Reserve, was being farmed. For the remainder of the century, the cultivated land included practically all of the rolling uplands with the addition of the "Shack" prairie and the "Coleman" prairie. Most of the marsh, except the wetter portion of the "great marsh" southeast of Chapman Lake, was being mowed for marsh hay, with intermittent fires being set to stimulate production. The oak opening and low prairie around present day Turner Pond and the floodplain forest were grazed, encouraging the spread of thorny shrubs. The ridges succeeded into forest in the absence of fire and grazing, probably remaining undisturbed until intensive cutting for firewood began in the late 1800s. In the mid-1880s, the clearings within the "Anchor" woods and "Susan's savanna" were brought under cultivation. Around the turn of the century, the "Draba" prairie was brought under cultivation, and the "Coleman" prairie was abandoned. Farms were diversified with the most important crops being corn, oats, spring wheat, and potatoes. Sheep were the most important animal stock.

Equally dramatic changes occurred on the Leopold Reserve lands in the early 1900s. Between 1910 and 1920, farmers dug drainage ditches across the "long marsh" west of Chapman Lake. In the 1920s, cultivation of the riverbottom openings ceased. Grazing of the wetlands east and west of what is now the Terbilcox house began. In the late 1920s, the "island" north of the Shack, currently part of the mainland, was logged. The marsh burned for the last time. In the early 1930s, the "Shack" prairie was abandoned. Unfortunately, the agricultural census records covering much of this period were destroyed in a fire, making it impossible to reconstruct the precise record of cultivation.

Leopold Era (1935–1949)

The Leopold era was a transition between older farming practices and modern mechanized agriculture, and the beginning of a land restoration movement. The depression and drought of the 1930s had taken their toll on the Reserve lands, with one farm being abandoned, the house burned down, and the property falling into the hands of the county. Aldo Leopold purchased this property in 1934; his friend Tom Coleman purchased an adjacent farm in 1937 (Fig. 2). With their purchases began a new attitude toward the land, whereby landowners started to reverse the process of land deterioration and to build it back to something like its pre-settlement condition. Toward the end of this era, new farming practices, particularly the use of tractors, made mowing the marsh hay or cultivating the small floodplain openings mechanically difficult and economically unfeasible. This, in turn, presaged the end of farming in the area.

About the time Leopold purchased his land, what is now the Leopold Memorial Reserve was still a relatively open, farming-maintained mixture of marshland (30% by relative area coverage), floodplain forest (24%), upland forest (19%), agricultural fields (17%), and oak savanna (10%) (Table 1). Leopold (1949) provides a description of the area:

> My own farm was selected for its lack of goodness and its lack of highway; indeed my whole neighborhood lies in a backwash of the River Progress. My road is the original wagon track of the pioneers, innocent of grades or gravel, brushings or bulldozers. My neighbors bring a sigh to the County Agent. Their fencerows go unshaven for years on end. Their marshes are neither

dyked nor drained. As between going fishing and going forward, they are prone to prefer fishing.

During the majority of Leopold's tenure on the Reserve, the floodplain forests were grazed but the upland forests were not (Leopold 1942; Liegel 1981) (see Fig. 2 for the locations on the Reserve of the parcels discussed in this section). The abandoned fields began to succeed back into prairie. The pines in the "Anchor" woodland were cut. The marsh areas were mowed until the mid-1940s when tractors became common among farmers on the Reserve. Grazing of the wetlands east and west of what is now the Terbilcox residence ended. Grazing of the "Kammerer meadow" began. Shrubs began to slowly invade the wetlands margins when cultivation and mowing ceased, fanning out particularly from the drainage ditch south of "long marsh."

Almost immediately after purchase of their farm, the Leopold family began the planting of thousands of native trees, particularly pines, and woodland shrubs and wildflowers (Leopold 1935–1949). Virtually all of the plantings from 1936 to 1938 died because of drought (Leopold 1936, 1937), but the family persisted and by the early 1940s the Shack was surrounded by young pine seedlings. In the late 1930s Leopold began to transplant prairie plants into the field in front of the Shack, a process which continued until his death in 1949. However, he did not burn the "Shack" prairie.

Agricultural Era (1950–1967)

Commercial farming for all practical purposes ended on the Leopold Memorial Reserve during the Agricultural era. The Reserve farms were simply too small, too infertile, and too varied in their soils and topography to lend themselves to modern farming techniques and the use of tractors and commercial fertilizers. Gentleman farmers, who for the most part rented out the larger and more fertile fields, replaced the older farmers throughout the Reserve. Shrubs and trees quickly invaded the riverbottom forests and marshlands when grazing and mowing ceased.

Farmer attrition occurred throughout the 1950s and 1960s (see Fig. 2 for the locations on the Reserve of the parcels discussed in this section). In 1947 Carl Anchor moved his house out of the Reserve. In 1955 Howard Kammerer purchased a farm, allowing only intermittent grazing of the riverbottom forest and of the "Kammerer meadow" just east of the farmhouse. In 1956 Russ Van Hoosen inherited a farm, ending grazing of his property. In 1957 Frank Terbilcox purchased a farm, ending grazing of his property. In the early 1960s the construction of the interstate highway put an end to the agricultural use of the Sinner Property. In 1961 Charles Anchor inherited a farm and ended all agricultural activity. In 1962 Ray Turner ended grazing of the wetland shrub carr around present day Turner Pond.

The ending of agricultural activity on the Reserve lands began to have a dramatic effect on its character and ecology. The previously cultivated fields continued their succession into prairie. Prickly ash *(Xanthoxylum americanum)* began to fill in the previously open mixed floodplain forest and floodplain oak barrens. The wetland margins continued to succeed into shrub carr. And the shrub carr succeeded on low prairie sites into mixed hardwood forest.

With the death of Aldo Leopold in 1949 and the movement of his family away from Wisconsin, the restoration of the Leopold property ceased. The 1950s and 1960s were quiet times with little visitation and almost no management. In 1967 the Leopold family deeded the property to what is now the Aldo Leopold Shack Foundation. They established this family foundation in order to provide for maintenance of the Shack, not only for their own use but as a laboratory for continued ecological and restoration studies.

Leopold Reserve Era (1968–present)

The Aldo Leopold Memorial Reserve was created in 1968 as a cooperative private wildlife preserve memorializing Aldo Leopold. In response to a growing threat of recreational development in the Baraboo area, Reed Coleman, the son of Leopold's good friend and neighbor Tom Coleman, persuaded the other landowners surrounding the Leopold tract to pool their properties under common management funded by what is now the Sand County Foundation. The five landowners who cooperated in this private preserve were Reed Coleman, Franklin Terbilcox, the Leopold family, Russell Van Hoosen, and the Sand County Foundation. Robert Ellarson, one of Leopold's students, drafted a generalized management plan. Terbilcox accepted the job of Reserve Manager.

During the subsequent years, the Sand County Foundation began purchasing some of the adjoining properties. The Foundation purchased the Sinner Property in 1968, part of the Turner Property and the "island" in 1970, the Anchor Property in 1972, the Kammerer Property in 1977, the Ragan Property in 1982, and another parcel of the Turner Property in 1982 (Fig. 2).

With the creation of the Aldo Leopold Memorial Reserve, Leopold's land rehabilitation program of the 1930s and 1940s was continued and expanded to include the entire Reserve. The focus of the early to mid-1970s was predominantly on wildlife management. Reserve Manager Terbilcox cleared a network of trails, dug a number of duck ponds (Turner and Van Hoosen ponds, 1969–1970; Center pond, 1977), planted "wildlife patches" around the ponds and in part of the "long marsh" west of Chapman Lake, occasionally mowed the "long marsh," and burned the "Shack" and "Coleman" prairies (Fig. 2).

In 1976, eight years after the Reserve was established, Charles and Nina Leopold Bradley retired on the Reserve and began a student research program for ecological studies of the area. The Bradleys built the Study Center, with a laboratory and work area in the lower level (Fig. 2). The first Leopold fellows created a working base map and started a comprehensive inventory of the Reserve, including plants and plant communities (Luthin 1978; 1979; 1980), land-use and vegetational history (Liegel 1982; and the present report), palynology (Winkler 1985), glacial geology (Socha 1984), soils (Sharp and Bowles 1985), hydrology (Zolidis 1985), birds (Mossman and Reed 1978), and wildlife (Mossman 1980; Tohulka 1979).

During the late 1970s and up to the present, the focus of management efforts has been more on restoring and maintaining native plant community types once more common on the Reserve. Management efforts have included restoration of old fields into prairie, brush management in the low prairie and oak barrens, and thinning of the Leopold pines.

Today the Leopold Memorial Reserve is a relatively closed combination of upland forest (34% by relative area coverage), floodplain forest (26%), marshland (23%), oak savanna (6%), and cultivated fields (11%) (Table 1).

Vegetational Change Following European Settlement

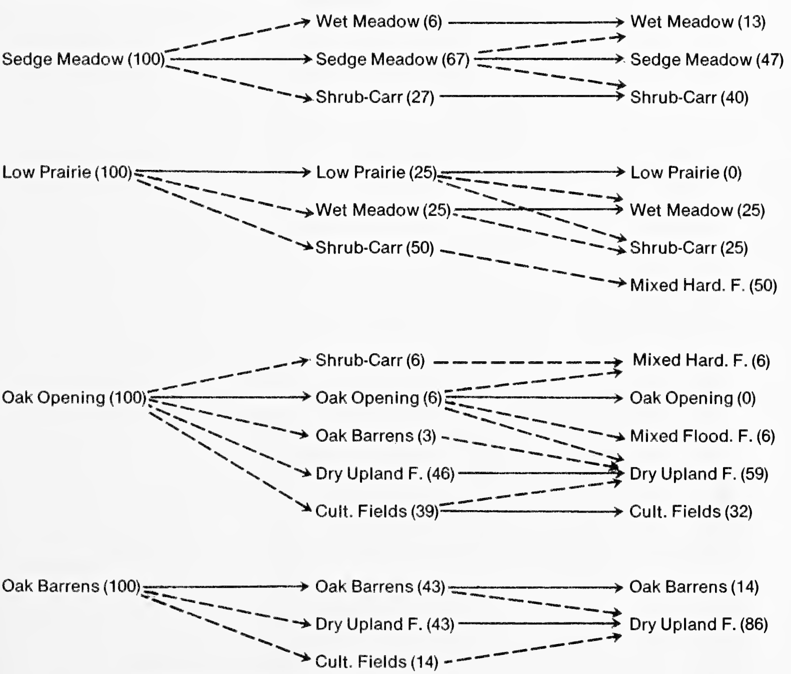
The preceding land-use chronology displays the panorama of vegetational change that has occurred on the Leopold Memorial Reserve during the last 13,000 years. The vegetation maps of the 1840s, 1930s, and 1970s, to be examined in this section, show more graphically the precise changes in percentage land cover by different plant community types since settlement, and the land-use factors responsible for these changes.

Ten natural and three disturbed vegetation types were identified as comprising the vegetation of the Leopold Memorial Reserve in the 1840s, 1930s, and 1970s (Fig. 3–Fig. 5). The relative area covered by each vegetation type for the different time periods is given in Table 1. Successional trends for selected plant community types between 1840 and 1980 are shown in Table 2. The characteristics of each community type are given in Table 3.

As previously discussed elsewhere (Liegel 1982), three interdependent factors seem to have been crucial in influencing the pattern and composition of the presettlement vegetation types on the Re-

Table 2. Successional trends in selected plant community types on what is now the Leopold Memorial Reserve, Sauk County, Wisconsin, between 1840 and 1980.

Plant Community Type during the 1840s	*% of Original Plant Community Type having succeeded into other types by the 1930s*	*by the 1970s*



serve: topography, hydrology, and fire. Four land-use factors seem to have been crucial in influencing the pattern and composition of the post-settlement vegetation types on the Reserve: fire control, grazing, mowing, and cultivation. The probable role of these land-use factors in vegetational change on the Reserve will be analyzed by examining successional trends in the following community types: (1) oak opening, (2) oak barrens, (3) sedge meadow, and (4) low prairie.

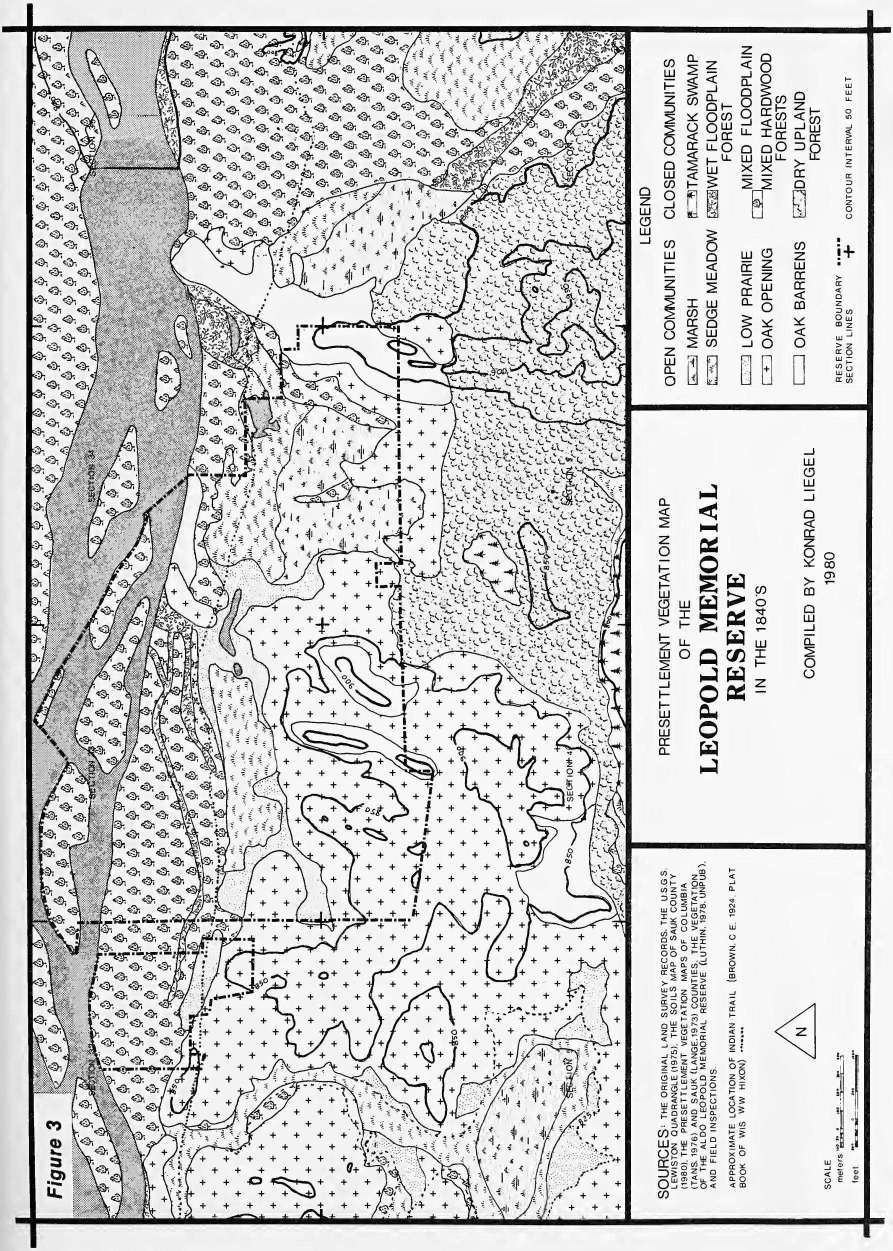
Oak Opening to Upland Oak Forest

Oak opening was the dominant plant community type on the Leopold Reserve at the time of settlement, covering almost one-third of the total land surface (Fig. 3;

Table 3. Characteristics of the plant community types on the Leopold Memorial Reserve, Sauk County, Wisconsin.

Plant Community Type	*Ecological Characteristics*
Aquatic	Continuous standing water at least 12″ deep, dominated by submerged aquatics
Emergent Aquatic	Shallow standing water through much or all of the growing season, dominated by cattail *(Typha latifolia)* and river bulrush *(Scirpus fluviatilus)*
Sedge Meadow	Saturated organic soils, dominated by sedges (*Carex* spp.)
Low Prairie	Grassland commonly inundated in the spring, dominated by big bluestem *(Andropogon gerardi)*, bluejoint *(Calamagrostis canadensis)* and cordgrass *(Spartina pectinata)*
*Wet Meadow	Disturbed sedge meadow, pastured low prairie, or weed community found on man-made pond spoils
*Shrub Carr	Shrubland dominated by shrubs or early-successional trees, such as aspen *(Populus tremuloides)*
Wet Floodplain Forest	Forest found along sloughs and old river channels, dominated by silver maple *(Acer saccharinum)*
Mixed Floodplain/ Mixed Hardwood Forests	Lowland forest dominated by river birch *(Betula nigra)*, ashes (*Fraxinus* spp.), prickly ash *(Xanthoxylum americanum)*, *(Pinus strobus)*, and, in mixed hardwood forest, by aspen *Populus tremuloides)*
Oak Opening	Savanna dominated by bur *(Quercus macrocarpa)* and white oak *(Q. alba)*
Oak Barrens	Savanna dominated by black oaks *(Quercus velutina, ellipsoidalis,* and *rubra)*, and, in the floodplain, by prickly ash *(Xanthoxylum americanum)*
*Dry Meadow	Former savanna disturbed by cultivation and/or grazing, dominated by Eurasian grasses and native prairie species
Dry Upland Forest	Forest dominated by oaks (*Quercus* spp.), black cherry *(Prunus serotina)*, and locally white pine *(Pinus strobus)*
*Roadsides	Composed primarily of hardy disturbance-resistant perennials, often of Eurasian origin
*Cultivated Fields	Agricultural fields subject to seasonal disturbance, dominated by annuals
	* man-induced plant communities

Figure 3


LEGEND
OPEN COMMUNITIES
MARSH
SEDGE MEADOW
LOW PRAIRIE
OAK OPENING
OAK BARRENS
CLOSED COMMUNITIES
TAMARACK SWAMP
WET FLOODPLAIN FOREST
MIXED FLOODPLAIN
MIXED HARDWOOD FORESTS
DRY UPLAND FOREST
RESERVE BOUNDARY
SECTION LINES
CONTOUR INTERVAL 50 FEET
PRESETTLEMENT VEGETATION MAP
OF THE
LEOPOLD MEMORIAL RESERVE
IN THE 1840'S
COMPILED BY KONRAD LIEGEL
1980
SOURCES: THE ORIGINAL LAND SURVEY RECORDS, THE U.S.G.S. LEWISTON QUADRANGLE (1975), THE SOILS MAP OF SAUK COUNTY (1980), THE PRESETTLEMENT VEGETATION MAPS OF COLUMBIA (TANS, 1976) AND SAUK (LANGE, 1973) COUNTIES, THE VEGETATION OF THE ALDO LEOPOLD MEMORIAL RESERVE (LUTHIN, 1978, UNPUB.), AND FIELD INSPECTIONS.
APPROXIMATE LOCATION OF INDIAN TRAIL (BROWN, C.E. 1924. PLAT BOOK OF WIS WW HIXON)
N
SCALE
meters
feet
SECTION 34
SECTION 35
SECTION 3
SECTION 4
SECTION 9
SECTION 10
900
850
800

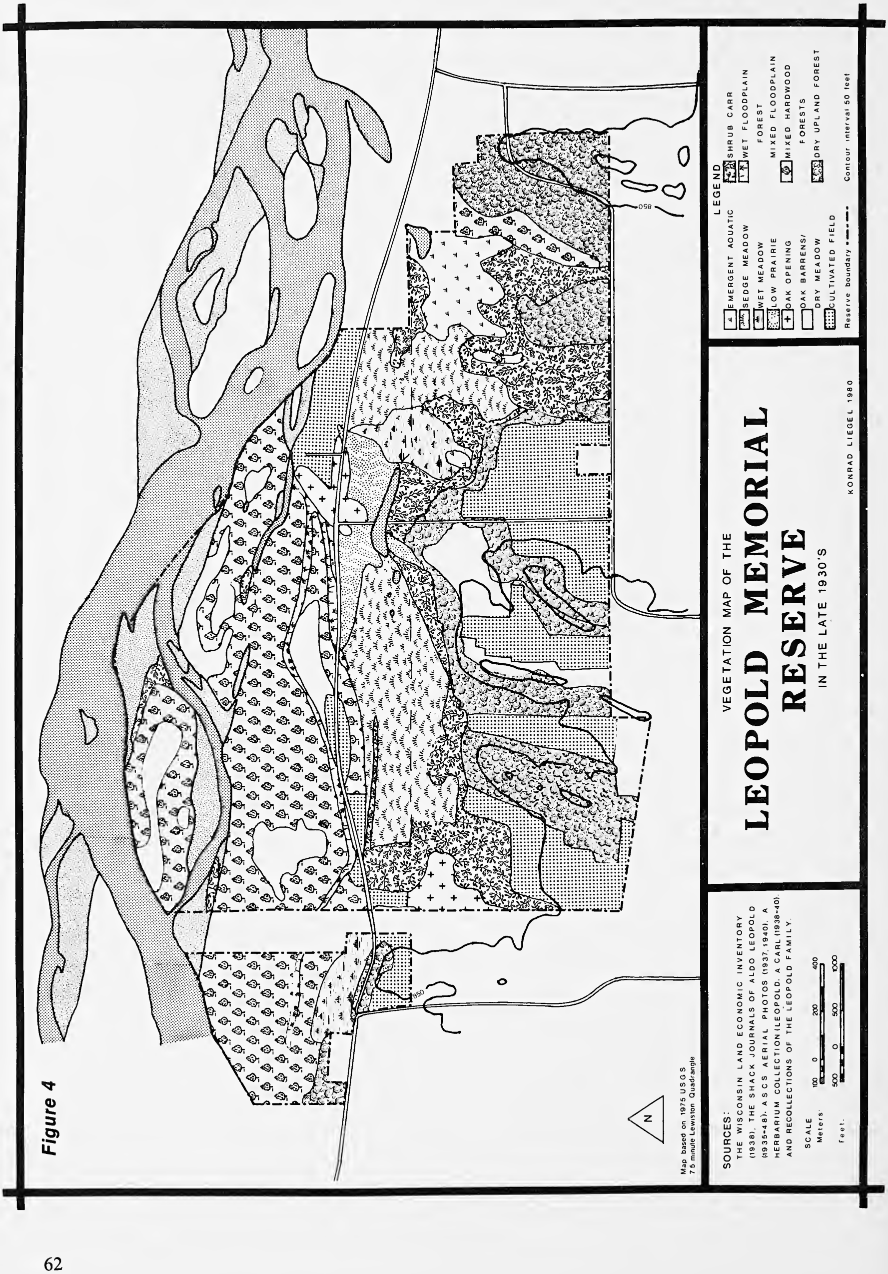

VEGETATION MAP OF THE
LEOPOLD MEMORIAL RESERVE
IN THE LATE 1930'S
KONRAD LIEGEL 1980
LEGEND
EMERGENT AQUATIC
SEDGE MEADOW
WET MEADOW
LOW PRAIRIE
OAK OPENING
OAK BARRENS/DRY MEADOW
CULTIVATED FIELD
SHRUB CARR
WET FLOODPLAIN FOREST
MIXED FLOODPLAIN
MIXED HARDWOOD FORESTS
DRY UPLAND FOREST
Reserve boundary
Contour interval 50 feet
SOURCES:
THE WISCONSIN LAND ECONOMIC INVENTORY (1938), THE SHACK JOURNALS OF ALDO LEOPOLD (1935-48). A S C S AERIAL PHOTOS (1937, 1940). A HERBARIUM COLLECTION (LEOPOLD, A. CARL (1938-40). AND RECOLLECTIONS OF THE LEOPOLD FAMILY.
SCALE
Meters 100 0 200 400
Feet 500 0 500 1000
Map based on 1975 USGS 7.5 minute Lewiston Quadrangle
N
850

Figure 4

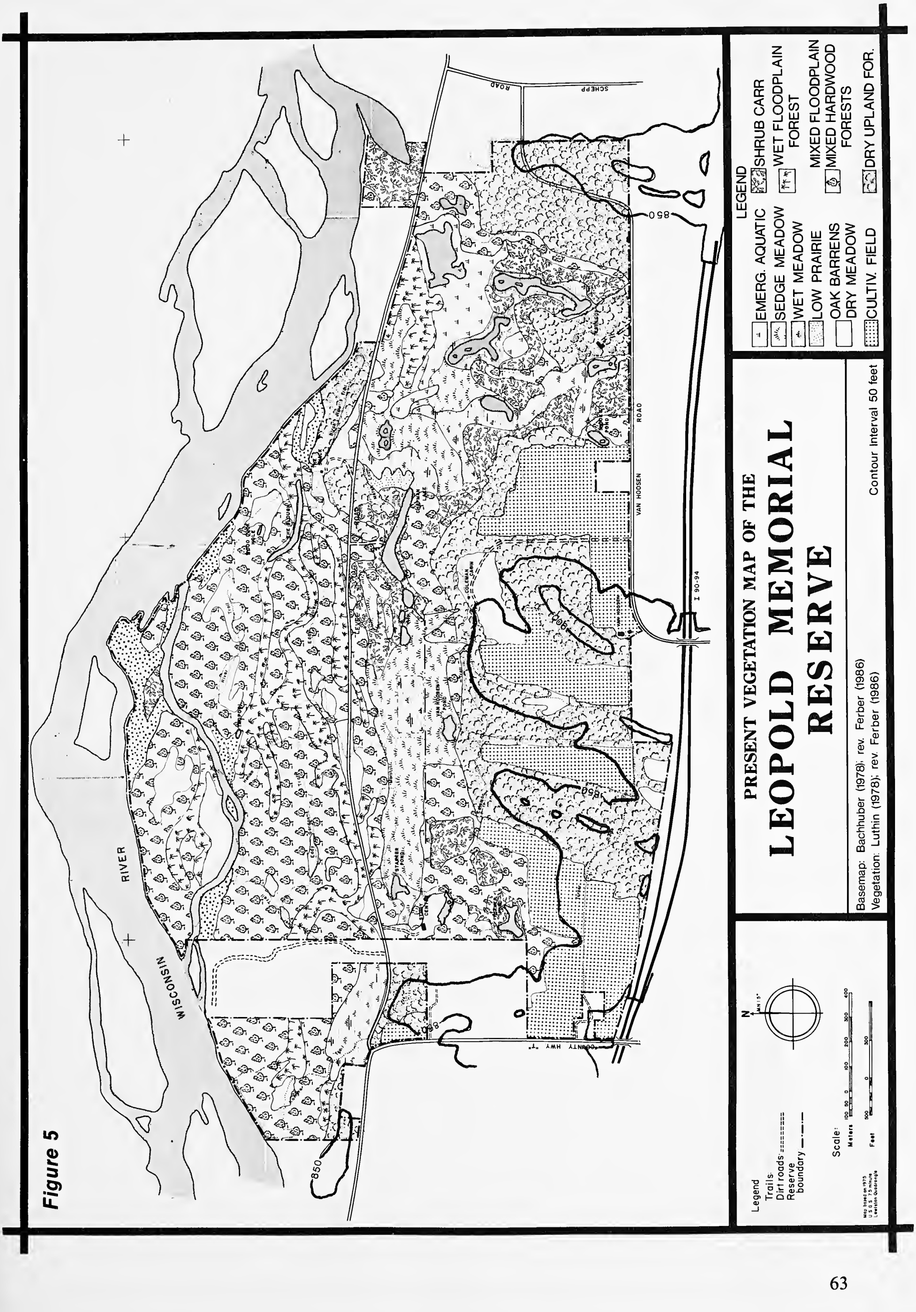


Figure 5
PRESENT VEGETATION MAP OF THE
LEOPOLD MEMORIAL
RESERVE
Basemap: Bachhuber (1978); rev. Ferber (1986)
Vegetation: Luthin (1978); rev. Ferber (1986)
Contour Interval 50 feet
LEGEND
EMERG. AQUATIC
SEDGE MEADOW
WET MEADOW
LOW PRAIRIE
OAK BARRENS
DRY MEADOW
CULTIV. FIELD
SHRUB CARR
WET FLOODPLAIN FOREST
MIXED FLOODPLAIN
MIXED HARDWOOD FORESTS
DRY UPLAND FOR.
Legend
Trails
Dirt roads
Reserve boundary
Scale:
Meters
Feet
N
WISCONSIN
RIVER
SCHEPP
ROAD
VAN HOOSEN
ROAD
I 90-94
COUNTY HWY "T"
850
900

Table 1). Today dry upland oak forest is the dominant plant community type of the Reserve; oak opening with an intact natural groundlayer is no longer present (Table 2).

After settlement, the rolling upland oak openings, which comprised about 40% of the oak openings, were cultivated. Most of the rolling upland oak openings remained under cultivation (Table 2). Meanwhile, virtually all of the ridge oak openings, which comprised about 50% of the oak openings, quickly succeeded into dry upland oak forest, due to the absence of fire and grazing. Thereafter, the oak forests were occasionally but never intensively grazed, and were also selectively cut for firewood. They remain dry upland oak forest today (Table 2). Finally, the lowland oak openings, which comprised about 10% of the oak openings, succeeded into shrub carr or were maintained by grazing until the early 1950s. Grazing may have maintained the lowland oak openings, but it destroyed the natural groundlayer. The lowland oak openings are mixed hardwood forest today (Table 2).

Floodplain Oak Barrens to Cultivated Fields to Floodplain Oak Barrens/Upland Oak Barrens to Dry Upland Oak Forest

Oak barrens were scattered on sandy sites throughout the Leopold Reserve at the time of settlement, occupying about 12% of the total land surface (about 5% of which is labelled as mixed floodplain forest in the 1840s map) (Fig. 3; Table 1). Today virtually all of the original floodplain oak barrens remain oak barrens, while 86% of the original upland oak barrens has succeeded into dry/upland forest (Table 2).

The floodplain oak barrens were for the most part cultivated after settlement, but were abandoned several decades later when the meager natural soil fertility ran out (Fig. 4). After abandonment, these "dry meadows" began to succeed back into a dry-mesic prairie, and now are oak barrens again. However, unlike the original floodplain oak barrens, today's floodplain oak barrens are invaded by prickly ash *(Xanthoxylum americanum)*. The ridge oak barrens, meanwhile, succeeded into dry upland black oak forest, due to the absence of fire and grazing, but at a slower rate than the ridge oak openings (Table 2). Unlike the white oak forest formed from former ridge oak openings, the dry upland black oak forest maintained an intact natural groundlayer, presumably because of the relatively open canopy and infertile soils (Curtis 1959; Vogl 1964). Therefore, the dry upland black oak forest on the Reserve easily lends itself to restoration, as demonstrated in the restoration of "Frank's" prairie (Holtz and Howell 1983) (Fig. 2).

Sedge Meadow to Wet Meadow and Shrub Carr

Sedge Meadow occupied about 15% of the total land surface of the Leopold Reserve at the time of settlement (Fig. 3; Table 1). Today about half of the original sedge meadow remains, the remaining half having succeeded into shrub carr or a disturbed version of the sedge meadow community known as wet meadow (Table 2).

Most of the sedge meadow on the Reserve was maintained from settlement through the mid-1940s by the periodic mowing of marsh hay. The remainder of the sedge meadow succeeded into shrub carr and wet meadow (Fig. 4). When mowing of the sedge meadows ceased in the 1940s, succession into shrub carr accelerated (Fig. 5). Drier hydrologic conditions, resulting from groundwater movement away from the marsh and toward the drainage ditch and from changes in river morphology, most likely also contributed to this successional trend (Bedford et al. 1974).

Stevens (1985) utilized the 1937 to 1975 aerial photographs to analyze the rates of shrub invasion on Reserve sedge meadow over time. Shrub cover increased in "long marsh" from 27% in 1937 to 50% in 1966 with a slight decrease due to mowing in 1955. South of the drainage ditch, the change was even more dramatic, with shrub cover increasing from 35% in 1937 to 83% in 1977.

Low Prairie to Shrub Carr to Mixed Hardwood Forest

Low prairie occupied about 8% of the total land surface on the Leopold Reserve at the time of settlement (Fig. 3; Table 1). Today, the low prairie has virtually disappeared as a community type on the Reserve, having been replaced by wet meadow, shrub carr, and mixed hardwood forest (Table 2).

In the absence of fire or mowing, or in the presence of grazing, about half of the original low prairie succeeded into shrub carr by the 1930s (Fig. 4) and ultimately into mixed hardwood forest thereafter (Fig. 5). Mowing delayed this succession in the low prairie near Chapman Lake (Stevens 1985) (Fig. 3–Fig. 5). When mowing ended in the late 1930s, shrubs quickly invaded, increasing from 17% in 1937 to 40% in 1949 but remaining constant until 1975 due to infrequent mowing. In 1975, shrub cover had reached 61% and has continued to increase ever since due to lack of mowing and burning.

Summary

The changes in vegetation on the Leopold Memorial Reserve since glaciation have been dramatic. The proglacial boreal forest and sphagnum bog communities of approximately 12,000 years ago have given way to the fire-maintained, relatively open oak savanna, marshland, and floodplain forest communities of pre-European settlement Wisconsin. These aboriginally influenced communities, in turn, have given way to the agriculturally influenced, relatively closed oak forest, shrub carr, cultivated field, and floodplain forest communities of today.

The character and appearance of the landscape of the Leopold Reserve has changed significantly since European settlement. At the time of settlement, two-thirds of the Reserve lands were composed of open communities of savanna and marshland; today, two-thirds of the Reserve is composed of closed communities of upland oak forest, mixed floodplain forest, and shrub carr. The primary factor responsible for this change is the control of fires that resulted from lightning strikes and Indian activities.

Agricultural use of the area helped to delay this succession of open communities into closed ones. Grazing and cultivation kept the savannas open but destroyed the natural groundlayer. The mowing of marsh hay, meanwhile, kept the low prairie and sedge meadow open. Agricultural use probably peaked in the 1920s, dropped throughout the 1930s, 1940s, and 1950s, and then leveled off in the 1960s. This decline in agriculture was due to the meager natural fertility of the soil, the introduction of modern mechanized farming, and farmer attribution.

Reflecting over the immense changes that had occurred since European settlement, an early pioneer of the township lamented in these somewhat florid words:

> Fairfield in pioneer days was a veritable flower garden. Wherever the sod was unbroken the ground was literally covered with flowers. It was a delight to look upon them and think that God and not man nor woman planted them and that Solomon in all his glory was not arrayed like one of these. There was one variety for which I looked in vain, the dandelion. The dear home flower, how I missed it and longed for the sight of it. The 2nd or 3rd year my sister, who was always looking for it as well as I, found just one and Mrs. Wing laugh-

ingly tells the story of Mrs. Emily how finding a dandelion and being so overjoyed that she shed tears. Neither was there a stalk of mullein to be seen in all the land. But we said: "with the coming of the sheep the mullein will grow," which has passed true and the time has come when we could dispense with the everlasting presence of both dandelion and mullein. (Luce 1912)

Acknowledgments

Many persons deserve special thanks for helping with this project. In particular, I wish to acknowledge the help the late Walter E. Scott gave in sharing with me his insights about the land-use history of the region and his extensive library of materials on Wisconsin. I also wish to thank Evelyn Howell (Department of Landscape Architecture, University of Wisconsin-Madison) and Kenneth I. Lange (Naturalist, Devil's Lake State Park) for their advice and editorial suggestions, my wife Karen Atkins for her assistance with producing the maps and figures, and Nina and Charles Bradley for their graciousness and generosity. I am also grateful to the Sand County and Aldo Leopold Shack Foundations; without their financial support during my four years of fellowship studies on the Leopold Reserve, I cound not have completed my studies.

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Collections of young-of-the-year Blue Suckers *(Cycleptus elongatus)* in Navigation Pool 9 of the Upper Mississippi River

Michael C. McInerny and John W. Held

Abstract. *Ten young-of-the-year blue suckers* (Cycleptus elongatus) *were collected in July 1979 and June 1980 from intake screens of a steam-electric station located on the east shore of Navigation Pool 9 (River Mile 678.5) of the Mississippi River. These blue suckers probably hatched in early May and may have been reared in the tailrace below Lock and Dam No. 8.*

The blue sucker *(Cycleptus elongatus)* is rare but widespread in the Missouri and Mississippi Rivers and their tributaries (Pflieger 1975). Dam construction resulting in reduced current velocity, increased siltation, and barriers to spawning migrations was thought to be responsible for the decline of this once abundant species (Cross 1967; Pflieger 1975). Blue suckers are rare in Wisconsin and are classified by the state as a threatened species (Wis. Dep. Nat. Resour. 1987). Johnson (1987) listed the blue sucker as a species of special concern in Minnesota. In Wisconsin, blue suckers are limited to the Mississippi River drainage (Becker 1983). Rasmussen (1979) reported that collections of blue suckers in Navigation Pool 9 of the Upper Mississippi River were rare between 1969 and 1979, but they were not collected in adjacent Pools 8 and 10. Blue suckers in Pools 8 and 10 had been collected before 1969.

Information on the life history of blue suckers is limited. Rupprecht and Jahn (1980) presented data on growth, food habits, and spawning in Navigation Pool 20 of the Mississippi River, and Moss et al. (1983) provided similar information for the Neosho River, Kansas, plus data on habitat use by all life stages except larvae. We report collections of young-of-the-year blue suckers from Navigation Pool 9 of the Mississippi River.

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John W. Held is a Professor of Biology and Microbiology at the University of Wisconsin-La Crosse.

Methods and Materials

Weekly 24-hr samples of fishes were collected from intake screens of Dairyland Power Cooperative's Genoa #3 steam-electric station from August 1978 through June 1980. Descriptions of the collection baskets used are described in McInerny (1980). Although not a traditional sampling gear, intake screens are practical and useful for qualitatively sampling fish populations in the vicinity of the intakes (Margraf et al. 1985). All fish collected were identified to species, measured (total length in mm), counted, and weighed (g).

Genoa #3, a coal-fired steam-electric station (350 MWe) is on the east shore of Navigation Pool 9 of the Mississippi River (River Mile 678.5) approximately 0.8 km downstream of Lock and Dam No. 8 and 1.2 km south of Genoa, Wisconsin. The intake structure of Genoa #3 was constructed along a rip-rap shoreline that extends from Lock and Dam No. 8 to approximately 0.8 km downstream of the steam station. The rip-rap generally consisted of large (>250-mm diameter) rocks.

River water temperatures on each sample day were obtained from plant personnel at Genoa #3. Current velocity at the surface was determined by measuring the time required for a semi-bouyant float to move a fixed distance. River discharge data at Lock and Dam No. 8 during sampling were obtained from the U.S. Army Corps of Engineers.

Results and Discussion

One blue sucker, 67 mm TL, was collected on the intake screens on 16 July 1979. Water temperature was 23°C and river discharge was 83,000 m^3/min. Nine blue suckers, ranging from 37 to 53 mm TL, were collected on 25 June 1980; water temperature was 22°C and river discharge was 50,000 m^3/min. Current velocity averaged 0.3 m/s at the shoreline and 0.8 m/s 20 m from shore. Current along the rip-rap shoreline in the vicinity of the intake screens presumably attracted these young-of-the-year blue suckers. Moss et al. (1983) reported that juvenile blue suckers in the laboratory preferred smooth substrates of fine gravel (>2 mm), large cobble (>128 mm) or bedrock (>256 mm) and preferred the strongest current (1 to 1.2 m/s).

We estimated that these blue suckers hatched in early May each year. These estimations were based on mean lengths of larval blue sucker at hatching (8.7 mm), and growth rates of 0.5 mm/da for larvae <23 mm TL and ~1 mm/da for larvae ≥23 mm (Semmens 1985). Water temperatures in late April/early May were 13 to 14°C, within the range (13 to 17°C) that Rupprecht and Jahn (1980) observed turberculated male blue suckers in obvious spawning condition (free-flowing milt) at Navigation Pool 20 of the Mississippi River. Larval catostomids were collected on 18 June 1979 and weekly from 20 May through 19 June 1980, but were identified only to family (McInerny 1980). Additional collections of larvae in Navigation Pool 9, along with improvements on identification of larval blue suckers (Yeager and Semmons 1987), could demonstrate that the tailrace of Lock and Dam No 8 is used by blue suckers for spawning and rearing of young. This information could be crucial for maintaining this species in Wisconsin.

Acknowledgment

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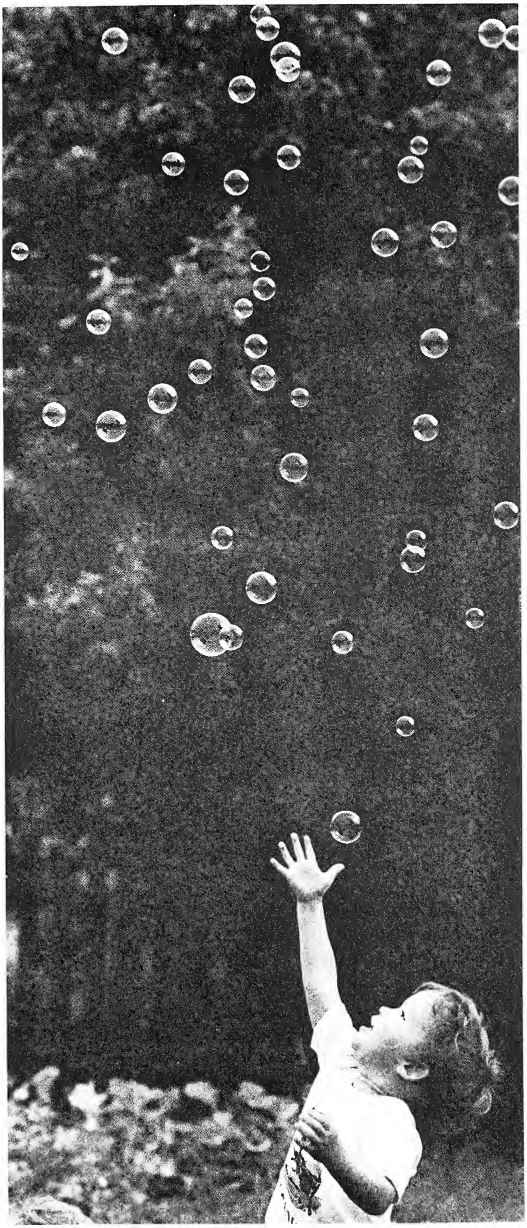
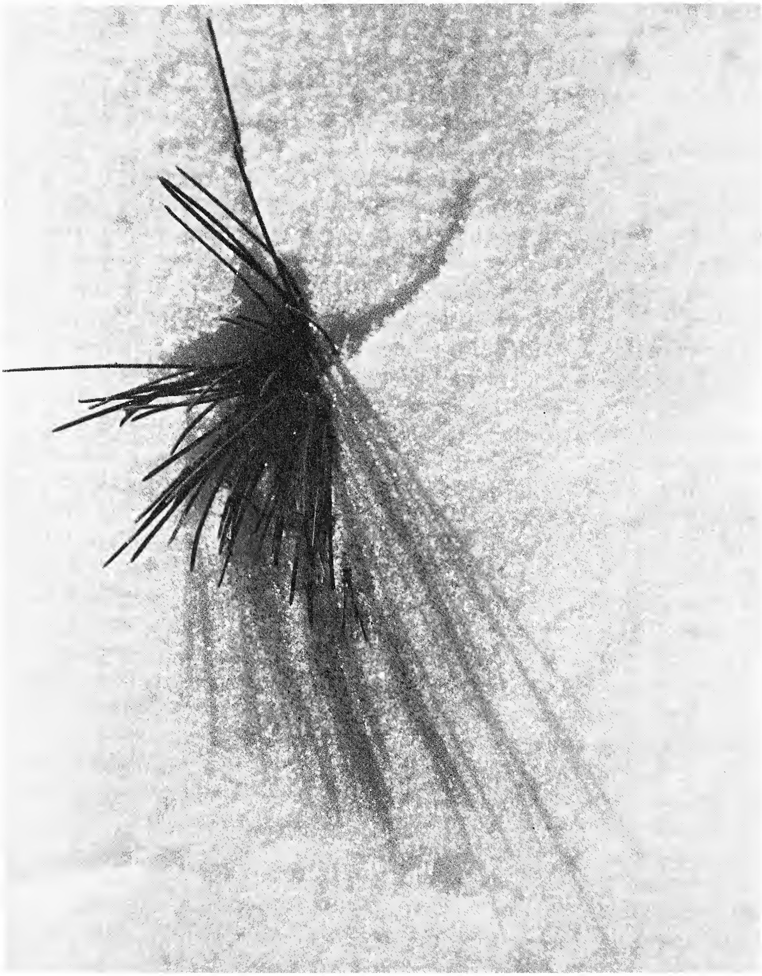
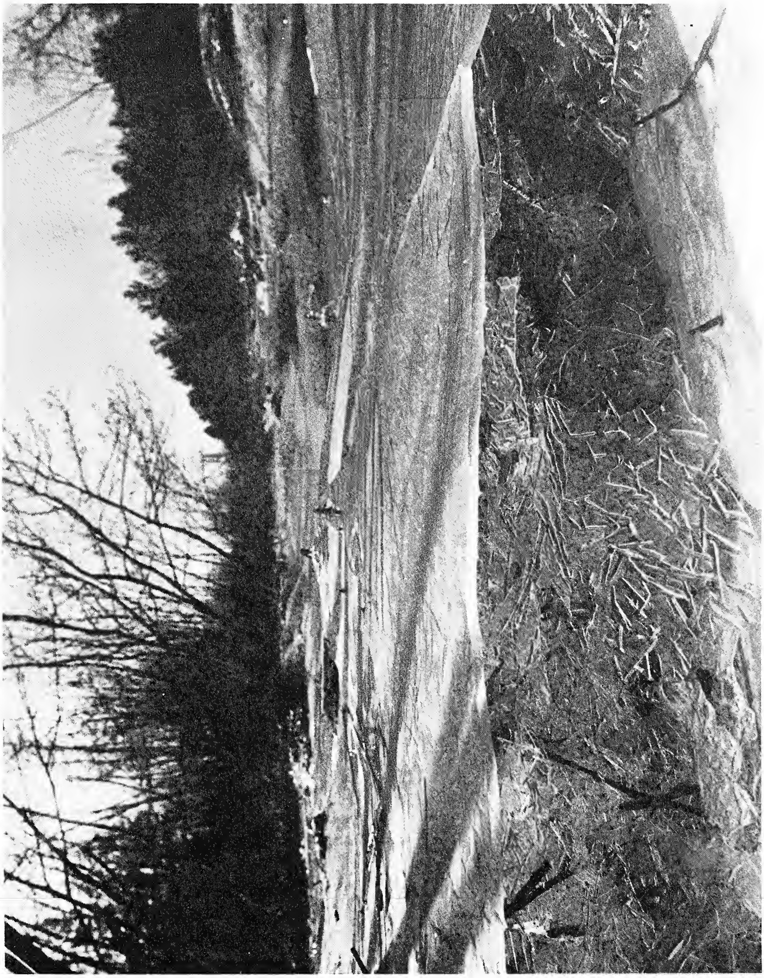
The Photography of David Ford Hansen

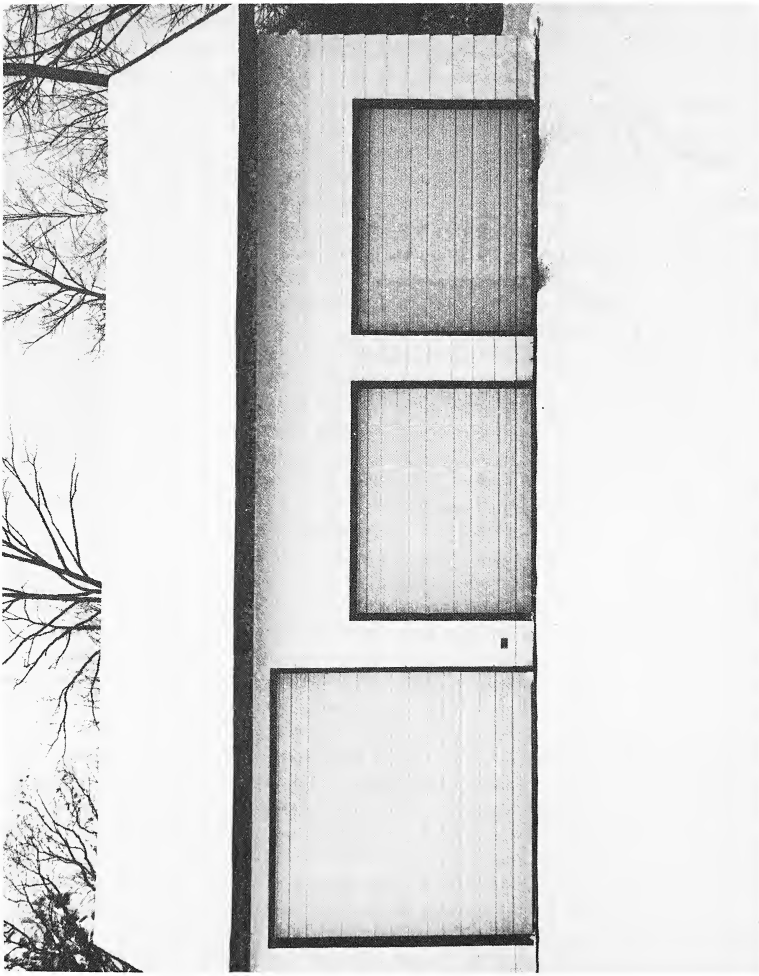
Those readers familiar with State photograph attributions have seen the name David Ford Hansen in virtually every major State newspaper and magazine. His photographs have illustrated three books about the Mississippi as well as a recent book on the Chippewa Valley. David is known not only for his technical skill but for his ability to capture universal human emotions. This collection of photographs, taken between 1973 and 1988, illustrates these two points. The technical skill demonstrated in the winter scenes allows the viewer to concentrate not only on the images but also on the contrasts, the starkness, and the incredible detail. In the three photographs of people, one encounters the joy and wonder of the young, the complexity of a boy on a bicycle, and the enigma of a young girl as she views herself in a mirror.

David Hansen teaches photography and writing courses as Assistant Professor of Journalism at the University of Wisconsin-Eau Claire.









Aging Effects and Older Adult Learners: Implications of an Instructional Program in Music

David E. Myers

A persistent concern in educators' attempts to meet the needs of an expanding adult clientele has been the relationship between learning and the aging process (Cross 1981; National Center for Education Statistics 1983; Gamson 1984). Despite longstanding evidence of diminishing cognitive, perceptual, and motor skills associated with increasing age (Chapanis 1950; König 1957; Lebo and Redell 1972; Salthouse 1979, 1982; Botwinick 1984), the practical effects of such declines in learning performance have not been clearly established. Some researchers suggest, for example, that the normal and expected effects of aging may have only limited negative effect on the tasks of everyday life (Schaie and Parr 1981). As learners, older adults may overcome potentially adverse effects of age-related deficits by drawing on their considerable life experience, by using a broad range of compensatory strategies, and by selectively attending to matters of particular meaning or relevance (Schaie and Parr 1981; Perlmutter 1983; Labouvie-Vief 1985).

Historically, assumptions of less efficient learning among older adults have paralleled other more general negative attitudes and beliefs regarding aging (Botwinick 1984). Research based on laboratory tests has tended to support the view that older adults do not learn as fast or as much as younger adults. However, such research sometimes has been based on content and procedures having little familiarity or meaning for older adults (Demming and Pressey 1957).

Age-related declines in sensory processing and behavior time raise particular questions regarding older adult learners in a subject such as music, which incorporates sensorimotor skill development. Combinations of activities involving simultaneous listening, moving, singing, and playing instruments are considered central to music learning (Mark 1986); Gordon (1980) and Mursell (1958) have suggested that the inherent processes of music learning do not change with age. Gibbons (1982) found that elderly subjects desired music education programs because they wanted to improve their music skills. However, Gilbert and Beal (1982) found in a survey that adults over fifty-five expressed reluctance to participate in physically active, skills-based music learning.

Gardner (Brandt 1987–1988) has contended that assessment in the arts is fruitless unless people have had opportunities to become actively involved in artistic experiences. Thus, it is possible that older adults who have not participated in physically active music learning (or have not done so for an extended period of time) may express reluctance to participate in skills-based programs. Cross (1981) has suggested that development of education programs for older adults should not be based on conclusions from research confounded by situational variables but on investigations into the physical, psychological, and sociocultural characteristics of older learners.

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To date, almost no research has addressed questions of adult music learning in the context of characteristics observed in an implemented skills-based instructional program. In this study, the relationship between age and music learning was assessed within an implemented skills-based music fundamentals program founded on a widely tested model of instruction (Froseth 1983). The criteria providing a framework for the study were as follows: (1) an instructional program that provided sequential acquisition of skills and knowledge deemed integral to understanding in music; (2) accessibility and flexibility in adapting techniques and materials to the needs and interests of participants; and (3) a performance-based assessment model that incorporated fundamental musical response as a basis for comparing aspects of music learning among adults of various ages. These criteria helped to ensure both the validity of instructional practice and the focus of the research on the music learning process.

Purpose

The primary purpose of this study was to investigate the relationship between age and music-learning achievement among three age groups of adults. Ancillary purposes included age-group comparisons of learning rate and of self-perceived attainment. Implementation of an instructional model that merged sequential development of music skills and understanding with the needs and interests of participating adults was considered central to these purposes.

Research subjects were volunteers who responded to a call for subjects and a description of the program offered through newspaper advertisements, visits by the researcher to community and senior centers, and posters. They represented three age levels: 22–37, 50–59, and 60–76 years. Though nineteen others participated, analyses were limited to thirty-two subjects who attended at least sixteen of twenty offered hours of heterogeneous group instruction and completed a testing program. Of these, eight were in the youngest age group, six were in the middle group, and eighteen were in the oldest group. All participants considered themselves unskilled in fundamental music learning, and all were individuals who maintained active, independent life styles.

The instruction focused on the development of aural-discrimination learning as a foundation for musical understanding. Four primary response modes were employed: (1) kinesthetic response through movement to beat (steady pulse), tempo (faster and slower pulse), and meter (beat groupings); (2) singing, including aural imitation of melodic patterns sung and played by the instructor, association of melodic syllables with the patterns, and vocal performance from melodic notation; (3) instrumental performance, incorporating imitation of melodic patterns played by the instructor and heard on a tape, and performance of patterns from notation using a soprano recorder; and (4) vocal rhythmic response, incorporating aural imitation of patterns performed by the instructor, association of rhythmic syllables with patterns, and performance of rhythmic patterns from notation. Autoharp and guitar performance tasks were included but not tested. Instruction moved in sequence from imitative experiences in moving, listening, and singing through aural-verbal association skills (melodic and rhythmic syllables) and visual-verbal association skills (notation) to music reading and performance. Instructional technique consisted of presentations of material synchronized with tape-recorded musical backgrounds, modeling-imitation sequences, and opportunities for review, practice, and elaboration of presented materials.

Method

The study was designed as a cross-sectional assessment of learning achievement, learning rate, and self-perceived attainment. Performance behaviors taught in the program provided the basis for assessment of achievement. Five pretests were administered to obtain baseline data on levels of musical skills: musical discrimination, kinesthetic response to music, melodic imitation skills, and melodic and rhythmic reading-performing skills. Posttests included the same instruments for musical discrimination and kinesthetic response. Six additional posttests were devised to assess facets of achievement specific to the instructional program: melodic imitation and syllable association (singing); melodic imitation-playing skills (soprano recorder); melodic reading-singing skills; melodic reading-playing skills; verbal rhythmic imitation and syllable association; and rhythmic reading skills (verbal). Tasks included answering multiple-choice questions (musical discrimination), tapping a woodblock (kinesthetic response), singing (melodic and rhythmic), and playing recorder (melodic tasks).

Learning-rate observations were recorded on a three-point scale (1 = slowest, 3 = fastest) during portions of instructional sequences that used a tape-recorded musical accompaniment to maintain consistent music tempos and rates of content presentation for all learners. Two trained unobtrusive observers recorded data during seven class sessions in five categories of activities reflecting the instructional sequence used for each class. These categories were: kinesthetic response, rhythmic imitation and association skills (listening and chanting syllables), melodic imitation and association skills (listening and singing syllables), melodic ear-to-hand skills (listening and playing), and reading-performing skills.

Self-perceived attainment was assessed by means of a questionnaire. Subjects used a five-point scale to indicate self-perceptions of their enjoyment, the personal value of learning tasks, their success on learning tasks, their progress over the course, and their overall levels of participation. In each category, responses were requested for specific learning activities emphasized in the instructional program: movement, melodic syllables, rhythmic syllables, music reading, recorder playing, autoharp/guitar experience, and applications in performance.

Age-group comparisons of the data were made on the basis of appropriate parametric and nonparametric measures, including t tests, analyses of variance and covariance, the Mann-Whitney U test, the Kruskal-Wallis analysis of variance by ranks, correlations, and the chi-square test. Because the sample was small and nonrandomized, nonparametric analyses were compared with parametric analyses for all data. Results consistently were similar. Because of the widely documented lessening of aural acuity associated with age, all subjects received a hearing screening administered by a certified audiologist.

Pearson product-moment correlations for inter-rater evaluations for three judges on achievement tests ranged from .97 to .99. Inter-rater reliabilities for two judges on unobtrusive observation of learning rate ranged from .81 to .99.

Findings

Instructional Efficacy

Statistically significant achievement ($p < .05$) in musical discrimination and kinesthetic response, assessed by paired t pretest–posttest comparisons, was attained in all age groups (Table 1). Posttest means on remaining measures indicated achievement among all age groups (Table 2).

Table 1. *Pretest-Posttest Mean Comparisons for Musical Discrimination and Kinesthetic Response*

Musical Discrimination						
Group	Pretest	Posttest	Diff.	S.D.	t	p
Youngest (N = 8)	30.25	35.13	4.88	5.82	2.37	.049
Middle (N = 6)	27.50	37.17	9.67	3.67	6.45	.001
Oldest (N = 18)	28.50	34.00	5.50	2.92	8.00	.000
All Groups (N = 32)	28.75	34.88	6.13	4.19	8.27	.000
Kinesthetic Response						
Group	Pretest	Posttest	Diff.	S.D.	t	p
Youngest	38.29	43.58	5.29	2.95	5.07	.001
Middle	31.44	37.67	6.22	4.04	3.77	.013
Oldest	29.67	37.39	7.72	3.73	8.78	.000
All Groups	32.16	38.99	6.83	3.66	10.57	.000

Achievement

No evidence was found to suggest declining achievement associated with increasing age. Statistically significant age-group achievement differences ($p<.05$) were found only on the assessment of melodic reading-singing skills. On this measure, the oldest age group was favored over the youngest age group. Both t test comparisons and the one-way analysis of covariance, adjusting for previous music learning experience and pretest achievement, supported this result (Table 3).

On pre-instructional levels of kinesthetic response, the oldest age group was significantly inferior ($p<.05$) to the youngest age group. On the posttest assessment of kinesthetic response, however, there were no significant age-group differences (Table 4). Thus, a pre-instructional kinesthetic disadvantage among the oldest learners was apparently diminished over the course of instruction. This finding is notable in light of physical limitations often experienced by older adults and in view of research findings suggesting a reluctance among older adults to participate in physically active, skills-based music learning (Gilbert and Beal 1982).

Aural acuity did not appear to be a factor in pretest, posttest, and change-score measures. Hearing patterns followed the documented trend of high frequency losses associated with increasing age (König 1957). Three subjects in the oldest group failed the hearing screening. However, all of these individuals realized achievement in the program. Inclusions and exclusion of failing subjects' achievement data did not alter age-group comparative analyses. A review of raw data, however, did indicate tendencies of failing subjects to score in the lower two quartiles on achievement measures. A notable ex-

Table 2. *Maximum Attainable Posttest Scores, Extreme Scores, Means, and Standard Deviations By Age Group*

Melodic Imitation/Syllable Association (Singing)

Group	Maximum	Extremes	Mean	S.D.
Youngest (N = 8)	80	18-78	56.63	22.72
Middle (N = 6)	80	26-78	57.00	22.16
Oldest (N = 18)	80	11-79	62.73	17.44

Melodic Imitation (Playing)

Group	Maximum	Extremes	Mean	S.D.
Youngest	54	25-52	36.58	8.44
Middle	54	11-47	31.67	12.04
Oldest	54	16-53	37.67	9.08

Melodic Reading (Singing)

Group	Maximum	Extremes	Mean	S.D.
Youngest	56	0-48	20.13	17.63
Middle	56	0-50	25.11	17.59
Oldest	56	0-54	36.78	18.37

Melodic Imitation (Playing)

Group	Maximum	Extremes	Mean	S.D.
Youngest	40	20-39	29.25	7.49
Middle	40	13-36	24.61	9.50
Oldest	40	20-39	30.04	5.83

Rhythmic Imitation/Syllable Association (Verbal)

Group	Maximum	Extremes	Mean	S.D.
Youngest	49	36-48	42.71	3.65
Middle	49	33-46	41.89	4.62
Oldest	49	31-46	41.33	4.63

Rhythmic Reading (Verbal)

Group	Maximum	Extremes	Mean	S.D.
Youngest	56	42-56	49.67	5.01
Middle	56	32-56	46.10	7.78
Oldest	56	24-55	46.87	7.25

ception to this trend was one failing subject's placement in the highest quartile on musical discrimination change scores.

Learning Rate

Learning rate, defined as immediacy of success on specific performance tasks, appeared to be slower for middle and oldest subjects than for youngest subjects in all five of the assessed categories (Table 5). Unpredictable attendance patterns, however, made consistent data collection and planned analyses impossible. Though an apparently slower learning rate did not seem to have an impact on achievement, there was some anecdotal evidence to suggest that learners in the oldest group were more inclined to practice between sessions than were their younger counterparts. Slower rates may thus have been compensated in the oldest group by increased effort and rehearsal.

Self-Perceived Attainment

Analyses using the Mann-Whitney U test and the Kruskal-Wallis one-way analysis of variance by ranks indicated that self-perceived attainment scores were stronger for oldest than for youngest learners in five categories: overall participation; overall attainment in melodic syllables tasks; participation in melodic syllables tasks; enjoyment of melodic syllables tasks; and enjoyment of music reading tasks ($p<.05$). On recorder-playing tasks, however, oldest learners' self-perceptions of their success were significantly lower ($p<.05$) than those of youngest learners (Table 6).

Qualitative Observations

Qualitative observations recorded by the researcher following each instructional session and during individual testing supported quantitative findings. Oldest subjects responded more favorably than youngest subjects to melodic singing tasks. Though youngest subjects appeared to demonstrate greater rhythmic responsiveness than those in the middle and oldest groups, no quantitative results supported this observation. A distinctive trait of the oldest group was the stability of attendance patterns in contrast to less consistent attendance patterns of the youngest group. At eighty years, the oldest participant did not complete the testing program but did improve markedly in his ability to discriminate pitch and perform accurately in singing and playing recorder. He reported that he believed the results of his participation would have been no different at age thirty from those realized at age eighty.

Discussion and Implications

Evidence obtained in this study suggests that increasing age may not be a disadvantage for older adult participants in performance-based music learning programs. Not only was there an absence of diminished achievement among older adults, but those subjects in the oldest age group scored significantly higher on melodic reading-singing tasks than those in the youngest age group.

In relation to the superior performance of older adults on the melodic reading-singing assessment, it must be noted that adults in the oldest group clearly were more comfortable than those in the youngest group with learning tasks that involved singing. It is possible that generational differences contributed to this result. Older adults were perhaps more likely to have experienced family and social group singing during their youth. In addition, the popular musical idioms of their young adult years were no doubt strongly melodic, perhaps establishing lifelong predispositions toward melodic sensitivity and singing tasks.

Another facet of older adults' singing inclinations may have been that singing was once a primary element not only of music education programs but of school

Table 3. *Age-Group Comparisons of Melodic Reading-Singing Skills*

Assessment

Group	Mean	S.D.	t	p
Youngest (N = 8)	20.13	17.63		
Oldest (N = 18)	36.78	18.37	−2.16	.04

One-way Analysis of Covariance Table

Source	df	ss	ms	F	p
Equal Adj. Means	1	1508.00	1508.00	6.30	.02

Table 4. *Kinesthetic Response Comparisons for Youngest and Oldest Age Groups*

Variable/Group	*Mean*	*S.D.*	*t*	*p*
Pretest				
Youngest (N = 8)	38.30	9.13		
Oldest (N = 18)	29.67	6.73	2.70	.01
Posttest				
Youngest (N = 8)	43.58	8.39		
Oldest (N = 18)	37.39	8.22	1.76	.09

Table 5. *Mean Age-Group Learning Rates Over Seven Assessments*

Variable	*Youngest (N = 8)*	*Middle (N = 6)*	*Oldest (N = 18)*
Kinesthetic Response	2.92	2.53	2.46
Rhythmic Imit./Assoc.	2.86	2.68	2.74
Mel. Imit./Assoc.	2.83	2.50	2.72
Mel. Ear-to-Hand (Rcdr.)	2.78	2.45	2.64
Reading/Perf.*	2.83	2.64	2.66

* Only six assessments were made in the Reading/Performance category.
(3 = fastest rate)

Table 6. *Comparisons of Oldest and Youngest Groups on Self-Perceived Attainment*

Category	*Average Rank Youngest (N = 8)*	*Average Rank Oldest (N = 18)*	*U*	*p*
Overall Participation	8.94	15.53	35.50	<.05
Overall Mel. Syllables Attn'mnt.	8.37	15.81	30.50	<.00
Participt'n. Mel. Syll.	5.43	17.08	7.50	<.00
Enjoyment of Mel. Syll.	8.06	15.92	28.50	<.01
Enjoyment of Mus. Reading	9.06	15.47	36.00	<.05
Success in Playing Rcdr.	18.50	11.28	32.00	<.05

experience in general. Singing tasks, therefore, especially when combined with the reading skills that make melodies more accessible, may have been strongly congruent with older adults' existing connotations of music learning. Motivation for melodic singing tasks thus may have been stronger in the oldest age group. In addition, if melodic tasks had greater meaning, they were probably valued more highly than nonmelodic tasks.

Although in this study learning rate appeared to lessen with age, achievement was not affected. Oldest learners, however, were consistently more likely than middle and youngest learners to take advantage of elaboration offered immediately following controlled presentation segments. It is possible, therefore, that lack of diminished achievement among oldest subjects may have been related to these subjects' willingness to request repetition and/or explanation of material.

Stronger self-perceptions in the oldest group for participation and enjoyment in melodic syllables activities and for enjoyment of music-reading activities are consistent with achievement results favoring the oldest age group on melodic reading-singing tasks. Similarly, strong self-perceptions of overall participation among the oldest group parallel reports of high motivation levels among older adults documented in nonmusic studies (Kastenbaum 1979).

The less favorable self-perceptions of success among older learners on recorder-playing tasks, however, were not reflected on melodic imitation (playing) and reading-playing achievement measures. This result suggests the possibility of a dichotomy between real and self-perceived capabilities. Older learners may be subject to their own stereotypical notions of decreased capability, especially where psychomotor skills are involved. Particularly if they have experienced certain of the physical declines associated with aging, older learners may tend to feel less successful than younger learners on multisensory manipulative tasks. The importance of sequential, success-oriented instruction that enhances self-perceptions would thus seem to be paramount for older adults.

Music educators have long held that learning opportunities should be available to people of all ages. Further investigation of the trends suggested in this study, along with increased information regarding the developmental needs and interests of adults, will help ensure design of appropriate music education programs for adult learners.

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From Wisconsin Poets

Much of the poetry in this issue has been informed by the area in which the poets live and work. Most apparently this is demonstrated in the sense of living history, whether recent or remote, in poems such as "The Mission of Birds" by Frank Smoot, which draws its title and inspiration from the 1898 Black River Falls high school yearbook, and in "Trees," a dark and terrifying sestina by Sara Rath, which was occasioned by an excerpt from the *Wisconsin State Journal* in 1987.

Broader influences and concerns are evidenced in the stark landscapes of John Judson and Denise Panek—the former, one of the most consistent and recognized, the latter one of the newer and most promising poets living in Wisconsin. Even the savage irony involved in land-locking the oceanic passions of Tristan and Iseult, or Aphrodite and Neptune, into a prairie cornfield as does Gianfranco Pagnucci in "La Mer La Mer," or the microscopic attention to naturalist detail of Travis Stephens' poems can best—though not, of course, exclusively—be appreciated within a Midwestern context.

Finally, the indictments—delicate or immense—of first "Christy," then "The Children of Nicaragua" by J. D. Whitney, or the absolute poetic mastery displayed in Dick Terrill's "The Azaleas" or "Azaleas"—which begins with the problems of love, particularly lost love—transcend any geographical concerns, and speak to the scope and variety of subjects and attitudes displayed by Wisconsin poets today.

The Mission of Birds

Black River Falls, Wisconsin, 1898

This girl, dead or past a hundred,
who under a tall jack pine
lay all afternoon and wrote a speech
about *The Mission of Birds,*
is lying in a photo album
wearing her best print dress,
just failing to look stern enough.

It's the same dress she lifted as she climbed
the stairs of the platform in the gym
to give that speech—keeping the promise
of the motto of her class,
"We'll find a way or make one."
She married a Falls boy three years older
who also finished school,
raising a hand to his class motto,
"Work is the law of life."

*

At that abandoned house they'd built
fall is a tragic afternoon,
each dusk more slender
than the last, the light gone early
toward winter solstice—their fumbling desire.
A hawk hunts the wreckage of an elm
for mice, against all hope.

Frank Smoot

Frank Smoot is currently finishing a graduate degree in poetry in Vermont. He has edited an anthology of poetry and fiction and served as editor of several Wisconsin poetry magazines. When not in Vermont, he and his wife Susan Enstrom (a musician and artist) live in Milwaukee.

Making History

for my mother

"Watch the hands," she says, "if he moves
his hands like this, she also moves like that.
The skates, arms, eyes are parallel like one dancer."

My mother has seen one son attempt suicide.
She has started new, at fifty, judging goats—
she made all the national journals this year.

And now she's watching Torville and Dean,
the British ice dance team, skating to *Bolero*.
It makes history, their perfection.

She's businesslike about the goats
and loves them and her tears at this
are like the stars caught in the ice.

Meanwhile my father, a gentle atheist
who has seen a son join the Catholic Church,
is in his shop, tinkering and drinking wine.

One time he spent the whole day
shaping hickory into a one-inch cube—
it's an impossible exercise in fine carpentry.

They spend their summer days
with the gate from shop to barn between them,
his hands like this, hers like this.

Frank Smoot

American Tale

The herring gulls increased over landfill
where Interstate signs directed tomorrow.

Lined with taxis, the streets dreamed of ending,
spoke in accents, dressed Italian,
denyed the black at their militant heart.

Then Saturdays came—cigars over bitter coffee,
newsprint news that came off on my hands.

Sundays were park swans, longing for children.
And when I told what I saw, they said:

The algorithm's not quite in your favor.
You must know computers, follow your broker
as the beggar does his one white cane—

This century won't be caught dead in poems.
Its epic is color, smaller camcorders,
Koreans out-researching the Japanese.

But in March, at light, I remembered a stream
seining through pastures, granite tucked
along shoulders where green

repeated its reasons.
And I forgot the width of pavements,
and walked, again, toward what first scented the air.

John Judson

John Judson teaches at the University of Wisconsin-LaCrosse and is editor for Juniper Press. His most recent book, North of Athens, *was published by Spoon River Poetry Press. His current poems are found in such diverse places as the* Kansas Quarterly, The Laurel Review, *and* Poetry.

Rivercliff: 1939

No children of divorce, no separation
enforced by law in our homes, all
distance had to be earned, all
privacy burned at alters mothers served,
gossiping by phone how good we were,
and thereby advertising affiliation.

So we took to the woods in gangs,
Robin Hooding the north shore of The Sound
a society structured and planned
by how close you lived to water:
some had houses moored
to docks that rose and fell
on what Wall Street walked upon;
others chained to dingys and yachts,
summer passage by wind
to darker sand, or islands
abandoned as Maine.

Until the War, when
older brothers and fathers left
and only some came back,
and the Coast Guard called upon us
for the duration
to drown light each night,
and those not working for Defense
went without four years of gas
or vacation.

John Judson

Snapshot 1: Ashland, Wisconsin, February 11, 1987

The great Lake Superior is white and black
open patches of darkness, a watery landscape
yesterday, 46, today the winds
leave blisters of ice
on the cars parked,
with their engines bleating at the cold—
from the car, people like us
read the historical markers
about Moningwanekoning and about
the Jesuits and the about the people
they called the Chippeways.

Snapshot 2: The German sisters, February 14, 1947, Black and White

Wearing white butcher's aprons
and hose that ended at the knee
black to match shoes and hairnets
over hair pulled back so tightly
the corners of their eyes tilted up
on sundays, the sisters watch televised mass
on the Zenith, the picture of Pope
Pius hung above the television console,
votive candles on ivory doilies—their houses
dark except for the dim artificial lights
of the manger scene complete with Star of Bethlehem
The setting took up half their living room area
until Mother's Day.

Snapshot 3: Farm Auction, Olney, Illinois, "The White Squirrel Capitol of the World," April 20, 1986

Tilted seed caps block the afternoon sun
while eyes follow the red and black chainsaw
Homelite, black and heavy, it goes for 25.
The Mennonite woman wears her bonnet
in an unusually reckless fashion
but it is too warm to keep
a bow tighted neatly beneath the chin—
somewhere a clang of horseshoes and old garden tools
are brought out into the open
like quarrelling roosters before a crowd of gamblers
they are examined quickly and then the
auctioneer raises the dusty crate
high above the crowd, asking
who will give him a dollar bill.

Denise Panek

Denise Panek lives in Eau Claire where she is Manager of Conferences and Institutes for the School of Arts and Sciences Outreach Program. She is a White Earth Ojibwe whose poetry and fiction have appeared in such journals as: Calyx, Sinister Wisdom, *and* Plainswoman.

La Mer, La Mer

Two porpoises along a sea coast would laugh
at you, white Aphrodite up from pastures of holsteins
and me Neptune of prairie corn, blackbirds in my hair,

laugh at how each summer we meet in the bed of the lake,
our feet planted in sand
and embrace seas of earthy emotions we hardly understand.

Sometimes we gulp water, and a land breeze laughs through the trees.

When a herring gull drops out of the air,
surveys the lake close up, east then west,
and goes off after the taste of salt in his nostrils,
we look up, remember a small hill of sand
and climb down toward our pond, laughing to ourselves.

Soon we shiver away from each other;
the gull's raucous cries come back from nowhere.

This far inland it's hard to imagine the sea.

Gianfranco Pagnucci

Gianfranco Pagnucci is a member of the English faculty of the University of Wisconsin-Platteville. His poetry has appeared in numerous periodicals and anthologies, and he has published three books of stories and poems with fourth and fifth books due to be published in the fall and winter, 1988.

Wildflowers for Dorothy

That was the summer I waited for darkness,
and told myself I didn't have time.
I pretended to ignore my friend,
who lived alone with her widowed father
and sold subscriptions to magazines.
She seemed as quaint and old fashioned
as a childhood fantasy I'd outgrown.

Each May Day I'd searched
for the earliest hepaticas,
wood-sorrel, buttercups, trillium,
yellow violets; wrapping a quaint
nosegay in a paper doily laced
with ribbon. I'd place it in Dorothy's lap
by her hand that lay like a dead white bird
on the shawl that concealed
her withered legs.

That summer I slipped books of Gothic romance
out of the village library and hid
in my bedroom to dream until twilight.
Later, Dick and I lay in the long wet grass
of the park behind the bandstand, pushing
adolescent bodies against each other
until our cheeks were chapped
and we were exhausted, breathless, from
silent passion in the streetlights' shadows.

The papery-thin whiteness of the dead
bird hand Dorothy waved in my dreams
was a haunting farewell.
That summer wood-sorrel and rue anemonoe
wilted in a jelly jar next to my bed.
I pressed violets between pages
of Teasdale's poems, plucked petals
from bloodroots and recited the frightening
litany he loves me, he loves me
not, he loves me . . .

Sara Rath

Trees

There are hiding places here no one has seen
but me. I crouch in shadows dark with night
beneath a sky of leaves along the edge
of pastureland nearby; these trees
and that oak grove the cardinal whistles from
remind me of my childhood and Grandpa's woods.

There'd been a slaughter house down in that woods
of childhood, where we played out gory scenes
with cowskulls in the grass, bleached remnants from
past decades, never going there at night,
too frightened by pale ghosts among the trees
or moss-crumbling walls at river's edge.

When I was twenty-nine I toed the edge
of danger and abandon in dense woods
much like these, dancing nude among the trees,
posed while a camera caught that jubilant scene.
I felt a reckless sense of joy that night,
a secret courage. I'd escaped from

rigid roles: wife and mother; from
identities that pressed me toward the edge
of thirty. But, ironically one night
much later—fifteen years perhaps, I would
suppress the memory of that pose, that scene.
A friend in prison wrote, "Watch out for trees!"

I asked him what that meant, and he said, *trees*
was prison slang for rapists. Coming from
a source like that, I now look at this scene
of mossy oaks and rocks with nervous edge.
They've found abducted women in our woods,
nude, chained to trees, shot dead. One more last night.

This summer women lock their doors at night
and walk outside with caution. Even trees
are threatening; I'll escape this woods
and others but there is no hiding from
the darkness that begins along this edge
foreshadowing the nightmares we will see.

As investigators combed the scene for clues last night
deer appeared at the edge of the trees
and wild turkeys called from the walnut and oak woods
in the valley . . .

excerpt from *Wisconsin State Journal*
Madison, WI August 6, 1987

Sara Rath

Sara Rath has been a freelance writer for over twenty years. Her third book of poems, Remembering the Wilderness, *received the Wisconsin Library Association's Banta Award while her most recent book* About Cows *won the Council for Wisconsin Writers award for best nonfiction book of 1987.*

Morchella esculenta

This musette is bulging with dinner
fit for the taking. Morels.
Along this dusty road they hide
in damp-sandy pockets where
the sun is slow to arrive.
"Good thing we beat the road grader,"
I say as you dash to the next cluster,
"if only all summer were as easy as this."

Later, at the pump,
you slowly pumping,
I wash sand from the waxy heads.
What a delicate fist is the mushroom,
locking so much in wafer ribs.

Like fish from the river,
berries from the woods,
a respite of luck
there for the taking.

Travis Stephens

Travis Stevens is a 1985 graduate of the University of Wisconsin-Eau Claire and most frequently writes of the northern Wisconsin dairy and pulpwood region. These poems, however, come directly from experiences of the past several years spent working in Glacier Bay, Alaska.

The Tiniest Crab

Walking the beachline out
beyond where tidal flats stretch,
where tide has just receded
we sift the sand
for becalmed offerings.
A crab is found,
shell intact but empty,
wide across as two fingers
side by side.

In that lacy fringe of seaweed scrap
at surf's farthest fingertip reach
we find more.
A Dungeness, a Tanner, both
empty and small, hollow,
and light as a flower.
And later,
the tiniest crab,
smaller than a fingertip
all legs intact, light as breath.
He comes with us wrapped
in a tissue, tucked into a pocket.
Tossed much farther than
the great ocean intended.

Travis Stephens

"The Azaleas" or "Azaleas"

"When you go," "If you go" begin two translations
of the great poem by Kim Sowol,
whose azaleas, which burn in version A,
are gathered twice on a green mountainside, or perhaps a hill.

Are the famous flowers in armfuls or in another measure,
    unspecified?
Is she through with him, or just sick and tired
is what choice we're left as the poet,
that lover who bids good-bye quietly
or without a word,
is left, we conclude, with emptiness.

Some evenings in her dim office we translated
the minor poets—Mi Kyung with dictionary,
her desk light a yellow island,
me with pacing coffee about to make
art out of the least utterance, out of
the brown creaking of her dusty chair.
Mostly her voice became soft
when she began to read
her finished drafts—title first,
inflection dropping in lyric pain—a cultural obsession—
followed by a dark pause for stillness:
"Spring Night"   "Paper Kite"
"To the Wind"   "Musky Scent"
"Rainy Day". . . . She was afraid, she said,
it would not sound the same or right in English

but it's all I can know, the translations, and so today
I will not weep or show tears,
perish or die, but want
to scatter, strew azaleas in her path
before her light, soft, gentle, gentle step.

Richard Terrill

Richard Terrill has received the Wisconsin Arts Board Literary Arts Fellowship and is currently a Regents Fellow in American Culture at the University of Michigan. He has been a Fulbright Professor of English in Korea and a Visiting Professor of English in the People's Republic of China.

The Children of Nicaragua

will disappoint us.
                                        Their faces
bright.
              The
depths of their eyes.
You could almost think
                                              if
less off-white
they were American.
They even smile.
If they are moving
                                        toward
a future
                it
is the wrong one.
They will disappoint us.
We want them
                              strong
& tireless
                  moving
relentlessly north
                                    great
bunches of fruit on their
backs for us.
Bananas.
                  Their
soft meat
                  delicate
& sliced
to grace our breakfast.

J. D. Whitney

J. D. Whitney lives and works in Wausau, Wisconsin. He is professor of English at the University of Wisconsin-Marathon Center and has published a number of collections of poetry including Hello, Tracks, The Nabisco Warehouse, Some, Tongues, Mother, *and most recently,* Word of Mouth *(Juniper Press, 1986) and* sd *(Spoon River Poetry Press, 1988).*

"Christy"

on
her back-
pack
blonde
7
maybe
8
a
hook where
one hand was
she
rides the bus.
She is
lovely
small &
clear light's
in her eyes.
She
&
friend
whisper
some out-
rageous thing
about
the
driver's
hairy ears.
He
is crabby
every
day
deserves it.
Warm
days
she
wears no
mittens
cold
days
one.

J. D. Whitney

Holocene Lake Fluctuations in Pine Lake, Wisconsin

Rodney A. Gont, Lan-ying Lin, and Lloyd E. Ohl

Abstract. *Middle and late Holocene water level fluctuations were inferred from a comparison of fossil diatom communities found in the sediments of the main basin and a bay of Pine Lake, Wisconsin. From 7500 to around 4500 years* BP *the water table was low enough to have kept the bay separated from the main basin. By 3765* BP, *the barrier had been overcome and the lake surface was near its present elevation. Based on an approximate 300 year subsampling interval, the water level has risen and fallen three times on a 1300 year cycle since 3765* BP *but has varied less than one meter in elevation.*

The surface level of a lake can be affected by a number of environmental factors. The effects of periodic drought, clearing of wooded watersheds by fires or logging, and blocking of drainage by dams last as long as half a century, but they usually persist far less than this (Charles and Norton 1986; Borman et al. 1974; Birch et al. 1980). More lasting are the changes wrought by climate, which often reach regional and even continental scale (Wright 1969, Webb and Bryson 1972, Webb 1981, Winkler et al. 1986).

Pine Lake (Fig. 1), an oligotrophic, soft water, seepage lake on the Chippewa-Rusk county line in West-Central Wisconsin, has characteristics that dampen short-term lake level fluctuations. This was evident during a three-year (1979–1981) monthly benchmark study when the surface level of Pine Lake varied less than 35 cm. Located on noncalcareous till of a stagnant ice-core moraine (Cahow 1976), Pine Lake has a surface area of 106 hectares, maximum depth of 33 meters, a small drainage basin of only 197 hectares, and a shoreline development index of 2.56 (Sather and Threinen 1963). Soils of the drainage basin are almost exclusively Amery sandy-loam (Ald), class 4e, 12–25% slope (D. Goettl, USDA SCS Chippewa County office, personal communication). Recent land usage has kept the surrounding terrain mostly wooded (95% wooded in 1963) and only approximately 50 summer homes rim the shoreline. In 1976 Pine Lake was included in the Wisconsin Department of Natural Resources Benchmark Lake Program as an example of an undisturbed lake system.

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Beauty Bay (Fig. 1), 2.4 hectares with a maximum depth of 15 meters, is located on the west side of Pine Lake. It is presently united to the main basin, but access is restricted by a submerged bar across the mouth of the bay. The apex of this bar, under approximately one meter of water, is comprised exclusively of boulders, apparently washed clean by wave action. The ground water flows from Beauty Bay toward the main basin (Tinker 1985).

A number of pertinent features are apparent on the USGS topographic map for the area (Chain Lake, WI N4515 W9122.5/7.5): 1) the immediate banks of both Beauty Bay and the main basin have a steep grade, 2) the system has an intermittent outlet, 3) there is a lack of agricultural development, and 4) no boggy or low areas are shown to directly abut either basin. A 1939 lake survey map

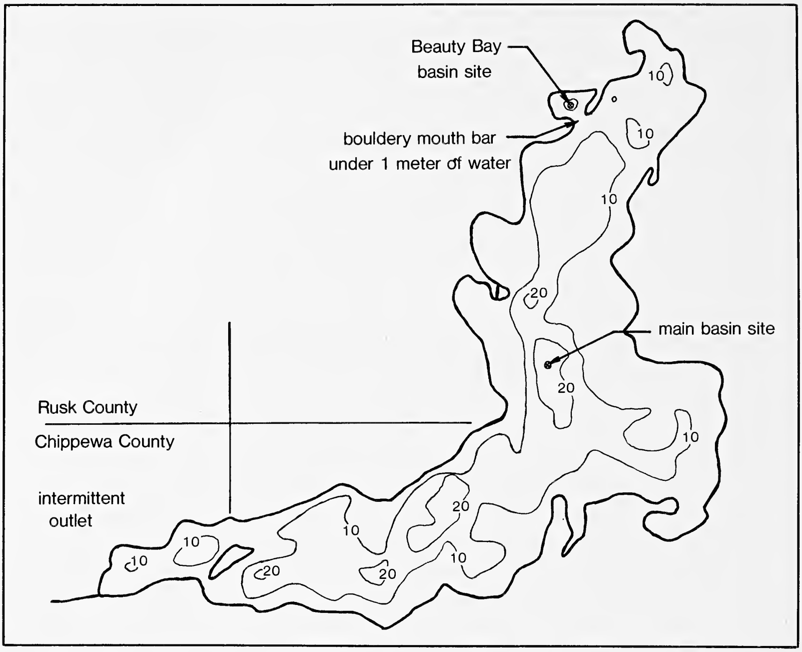

Fig. 1. Pine Lake, Wisconsin. Location of study sites in the main basin and in Beauty Bay.

of Pine Lake, compiled by the then Wisconsin Conservation Department using data from the WPA Lake Survey Project, indicates the immediate shoreline was completely comprised of upland woods of oak, oak–aspen, or pine. Recent cursory inspection of the surrounding woods confirmed the presence of sizable quantities of red oak *(Quercus borealis),* quaking aspen *(Populus tremuloides),* and white pine *(Pinus strobus)* directly at the lake front. In fact, one of the more noticeable features of both Beauty Bay and the main basin is the remarkable scarcity of aquatic macrophyte, lowland, and transition vegetation at the shoreline.

The oldest historic record of Pine Lake and its drainage basin is probably found in the original land survey conducted in the Pine Lake area in 1852. Features that would have been incidentally cited when encountered by the surveyor would have included Indian trails, roads, burned-over lands, and windthrows (Bourdo 1956). None of these nor any other human-related features were cited for the immediate vicinity of Pine Lake. The surveyor's description of Pine Lake at that time was "banks very high and steep, shores gravel and sand, water clear and deep, bottom sand, timber surrounding pond—Pine, maple, oak, and aspen." A present-day description would differ very little.

No direct evidence of historic human alteration of the bar separating Beauty Bay from the main basin was found. The 1972 Chain Lake, Wisconsin, 7.5-minute

USGS topographic map, both the 1948 and 1950 Weyerhauser, Wisconsin, 15-minute USGS topographic maps, and the 1939 Wisconsin Conservation Department Lake Survey Map all show Beauty Bay clearly united to the main basin. Alteration by pre-European natives might be conjectured, but there was no evidence for this and the bar appears to be a naturally deposited barrier, swept clean by wave action to leave boulders.

This study depended on the physical relationship of Beauty Bay to the main basin, the stability of the main basin, and the sedimentary record of fossil diatoms. The premise was quite simple. During periods of high water, when the mouth bar of Beauty Bay lay deeper beneath the surface, water would be more freely interchanged with the main basin. This would result in "contamination" of the littoral community of Beauty Bay with planktonic species adapted to the large, deep main basin. Conversely, when water levels were low, the bar would be covered by less water and could even be exposed. This restricted or blocked access to Beauty Bay would reduce, and possibly even eliminate, any similarity of the two diatom communities.

Procedure

In Beauty Bay a sediment core 320 cm long was removed using a Livingstone-style piston corer (Livingstone 1955). In the main basin the upper 115 cm were taken using a freeze-coring device (Swain 1973) while the sediment from 150 cm to 375 cm was extracted using the Livingstone corer.

During piston-coring, due to the depth of water over the study sites, a rigid pipe casing was assembled between the ice and the water-sediment interface. This casing, just slightly larger in diameter than the piston corer, was used as a guide to the proper location in the sediments and to prevent bending of the thrust rods during sampling. To increase penetration of the corer, two winches were attached, one end of each to the thrust rod of the corer and the other hooked under the ice. At maximum penetration, sufficient force was being applied to visibly flex the part of the thrust rod extending above the corer casing. Although the piston corer was forced into the sediments as far as possible, it would not penetrate a highly organic compact layer at 375 cm (7535 BP ± 135 yrs) in the main basin nor a similar layer at 310 cm (7565 BP ± 85 yrs) in Beauty Bay. This layer apparently is not a universal characteristic of Chippewa moraine lakes since the same corer was also used on nearby Oliver Lake #2 (Gont and Ohl 1985) to get sediments ^{14}C dated at over 11,000 years (unpublished data).

The piston cores were left in the sample tubes, frozen in the field, and taken to the laboratory where they were kept frozen during removal and subsampling. The freeze core was removed from the corer in the field, immediately wrapped in foil, and transported on dry ice to the laboratory, where it was kept frozen until subsampled.

Slices of sediment approximately 0.3 cm thick were cut from each core with a hacksaw at 10.0-cm intervals. This was later determined to approximate 300-year sampling intervals over the 4500-year time span when the two basins had prevalent species in common. These subsamples were oxidized using the hydrogen peroxide and potassium dichromate method (van der Werff 1953) and strewn-mounted (Patrick and Reimer 1966) on microscope slides using Hyrax (R.I. 1.65) as the mounting medium. In the main basin, random transects from a slide from each subsample were examined at 1250X with a Zeiss research microscope until a minimum of 500 (Stockner and Benson 1967, Weitzel 1979) diatom valves were identified and tabulated. Once the main basin prevalents were discovered, it was unnecessary to identify all frustules from the Beauty Bay subsamples, since only the "contaminants" from the main basin could affect the percent similarity index. A minimum of 500 diatom valves per slide were still inspected in the simplified count of each Beauty Bay subsample, but those species that had not appeared as prevalents in the main basin were tabulated as others. However, complete counts of 500 had been made at approximately 50-cm intervals along the Beauty Bay core in a preliminary study (unpublished data) and were available for reference. In all of the counts, the "dilution effect of dominants" (Kingston 1986) was not taken into account.

Dating was done by a ^{14}C method on 5-cm long core sections (minimum of 10g dry wt.) sent to the Radiation Laboratory of Washington State University (WSU sample numbers 3180–3187, 3189). Regional corrections for ^{14}C dates are available (Grootes 1983), but the dates in this paper have been presented as uncorrected.

Results

In the 34 subsamples examined from the Pine Lake main basin core, representing the last 7500 years, only three of the 212 diatom taxa identified were found in greater than 3% relative abundance in three or more levels. The distributions of these three, *Cyclotella stelligeroides* Hust., *Cyclotella comta* (Ehr.) Kutz., and *Tabellaria fenestrata* (Lyng.) Kutz. are shown in Figure 3. In the 32 subsamples examined from Beauty Bay, also representing the last 7500 years, the above prevalent species of the main basin suddenly appeared in relative abundance greater than 3% approximately 4500 years BP and remained as prevalent species in varying proportions to the present (Fig. 2).

Similarities of subsamples were determined by a $2w/(a+b)$ percent similarity index used by Bray and Curtis (1957), where w is the summation of the lowest count of each species in the two assemblages being compared, a is the total count from one assemblage, and b is the total count from the other. This index can range from 0 to 1—it equals 0 when the two assemblages to which it is applied have no species in common and 1 when all species are in common and the relative abundance of each species is identical as well. Because linear interpolation between ^{14}C dates was used to date many of the subsamples, correspondence between main basin and Beauty Bay basin subsamples could only be approximated. For this reason, a similarity index was calculated for two sets of data: 1) every Beauty Bay subsample and the nearest-aged main basin subsample and 2) every Beauty Bay subsample and the average of the two nearest-aged main basin subsamples. Both sets ot indices were similar ($r^2=0.93$, $p<0.01$) so only the data of set 1 were used in the analysis (Fig. 3). Subsamples with the greatest similarity to the main basin were labeled as high water levels and those with the least similarity as low water levels.

Discussion

An important consideration in any fossil study is how representative the sedimentary record is. This aspect was not directly tested in Pine Lake. However, diatoms have recently become the subject of numerous fossil studies investigating acid precipitation effects, and these studies have repeatedly reported that diatom remains in surficial sediments accurately represent the living community (Charles 1985, Haworth 1980).

The problems of sediment mixing and differential preservation of frustules have also been reviewed (Binford et al. 1983). By taking cores from the deepest part of the basin, the probability of mixing is greatly reduced (Kreis 1986). But even if

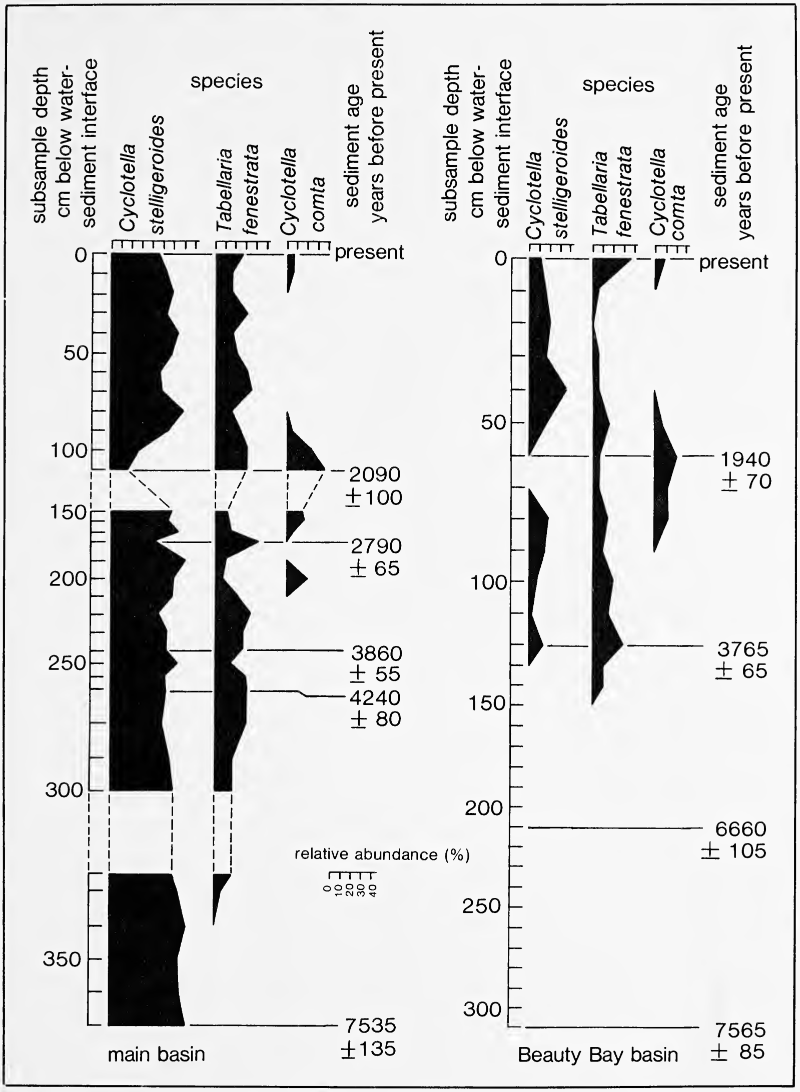

Fig. 2. Species that appeared in three or more subsamples at≥3% relative abundance in the sediments of the main basin of Pine Lake, and their abundances in the Beauty Bay basin. Sediment age rather than subsampling interval is on the linear scale. Each horizontal hash represents one subsample. Subsamples were taken every 10 cm along the cores. Sediment ages are uncorrected ^{14}C dates.

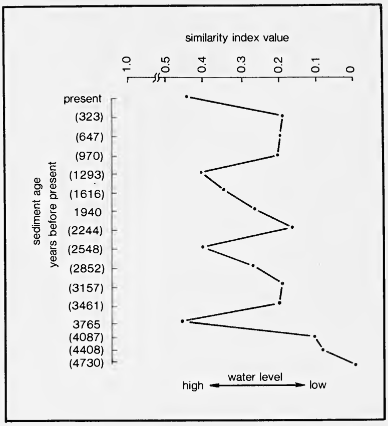

Fig. 3. Inferred water level fluctuations of Pine Lake over the past 5000 years. Similarity is based on a 2w/(a + b) index. Sediment ages in parentheses were determined by linear interpolation between ^{14}C dates. Those dates not in parentheses are uncorrected ^{14}C dates.

sediments were mixed on a small scale, to the order of tens of years (Davis and Smol 1986), it is unlikely that events on the scale of hundreds of years would be masked (Haworth 1980). The physical features of Pine Lake, in conjunction with the stable diatom community, also support an assumption of minimal disturbance of the sediments at the study site.

Eroded and broken frustules commonly occur in fossil diatom material. To test the extent of increasing dissolution and breakage over time all diatom valves and fragments with radial symmetry, identifiable to species or not, were counted on a sequence of eight microscope slides spanning the entire main basin core. On each slide at least 60 specimens were tabulated. Radial symmetry was used as the criterion because *C. stelligeroides,* a small radially symmetrical species, was the major prevalent in every core subsample. A ratio of "identifiable valves" to a total count, including "specimens not identifiable," ranged only from 0.765 to 0.821 with no trend detected from top to bottom of the core. Although it is obvious that a totally eroded valve is impossible to detect, it would be expected that valves eroded to the point of no longer being identifiable would increase with depth if dissolution over time were a problem. This did not seem to happen in Pine Lake, at least during the last 7500 years.

The remarkable simplicity and constancy of the diatom community of the main basin over the past 7500 years are evidence that any water-level fluctuations had little effect. The fact that there were only three prevalents, *C. stelligeroides, C. comta,* and *T. fenestrata,* which usually comprised 80% of the counts of 500 at all levels examined in the main basin, emphasizes this point. This has been attributed to several characteristics of the Pine Lake basin and its watershed. The lake's position in the very headwaters of the drainage was important because it limited the area that any surface drainage disturbance could affect. The steep slopes of the sides of the lake bed gave Pine Lake a large volume in relation to its surface, which diluted incoming nutrients. Although fire and windthrow undoubtedly hit the drainage basin, the results of these forces would have been patchy and irregular due to the uneven nature of the surrounding moraine. In any case, disturbed forested watersheds provide a surge of nutrients but rapidly recover (Borman et al. 1974). Pine Lake was able to absorb any short-term surges without showing detectable effects. Even post-European settlement disturbances, restricted apparently to logging and summer home development, produced minimal changes. In short, Pine Lake probably had minimal watershed disturbance and was well insulated from any disturbances that did occur.

Apparently the three main basin diatom

species thrived only in the open water of the main basin since, in the subsamples dated c. 7500 BP to 4500 BP examined from Beauty Bay when the two basins were inferred as being separate, not a single specimen of *C. stelligeroides, C. comta,* nor *T. fenestrata* was found. It was not until c. 4500 BP, and continuing to the present, that these three species appeared in Beauty Bay as prevalents. Even if isolated from the main basin, the proximity of Beauty Bay makes it unlikely that accidental introduction and establishment in the basin could have been avoided for the 3000 years prior to 4500 BP if water conditions were favorable. Whether they actually thrived after this time or were merely resupplied by water flow, it is probable that the presence of the three main basin prevalents in Beauty Bay for the last 4500 years was due to significant influx of water from the main basin.

Some information is always lost when raw data is condensed. In Pine Lake, the reference basin (main basin) had only the same three prevalent species in all subsamples of the core. Since the remaining nonprevalent species not used in the analysis, amounting cumulatively to less than 20% of each count of 500, were divided among at least 30 additional species at each sediment level examined, it is unlikely that the abundance of any one of these species, or even several of them, would materially affect the similarity comparisons to Beauty Bay. This is reinforced by the index itself, which treats each individual equally and does not give weight to species out of proportion to their abundance (Kershaw 1968). Variations in similarity values of equivalently aged main basin-Beauty Bay subsamples would thus be a function of the degree of "contamination" of Beauty Bay with the three main basin prevalents.

It should be mentioned that Beauty Bay had a great many other prevalents (unpublished data), but since the focus was on Beauty Bay "contamination" by main basin species and not on the community dynamics of Beauty Bay itself, this would not create a problem—as long as productivity in Beauty Bay remained relatively constant. To determine roughly if major changes in productivity took place since the inferred water level rise that united the two basins around 4500 years BP, preliminary counts of 500 valves each for three sediment subsamples from Beauty Bay within this span were examined. *Pinnularia biceps* Greg. was recorded at 9.2%, 16.3%, and 22.5% relative abundances at 0 years BP (0 cm), c. 1616 years BP (50 cm), and c. 3157 years BP (100 cm), respectively; *Synedra tenera* W. Sm. was recorded at 8.5% relative abundance at 0 years BP (0 cm); and *Navicula pupula* v. capitata Skv. and Meyer was recorded at 8.2% and 10.7% relative abundance at c. 1616 years BP (50 cm) and c. 3157 years BP (100 cm), respectively. No other species, besides the three main basin prevalents, were found in greater than 5% relative abundance during this time. The maintenance of only the same six most common species over the past 4500 years would indicate that productivity did not greatly change during this time.

Prior to c. 4500 years BP the diatom community of Beauty Bay was quite different. Instead of the six species cited in the previous paragraph, *Stauroneis anceps* Ehr., *Melosira islandica* O. Mull., *Melosira italica* (Ehr.) Kutz., *Fragilaria construens* v. *venter* (Ehr.) Grun., *Synedra famelica* Kutz., and *Fragilaria brevistriata* Grun. were most prevalent, all reaching greater than 10.0% relative abundance at one time or another in the preliminary counts (unpublished data). A major difference like this would be expected if the two basins were separate prior to 4500 years ago and united after that time.

Based on the degree of similarity between the Beauty Bay and Pine Lake diatom communities and roughly a 300-year sampling interval, dependent on sedimentation and compaction rates, the following sequence of surface fluctuations were inferred (Fig. 3):

1. From 7500 to c. 4500 years BP, the water table was low enough to keep the Beauty Bay basin separated from the main basin by a ridge. During this time span there were no main basin prevalents found in the Beauty Bay basin.

2. At c. 4400 BP main basin prevalents were first found in Beauty Bay and by 3765 BP the two communities had a similarity index of 0.469. This is comparable to the 0.444 index at present. Once the barrier between basins had been overcome at c. 4400 BP the lake level stabilized near its present level.

These first two inferences concur with the existence and timing of a Middle Holocene dry period, discussed by Winkler et al. (1986) and supported by 19 regional studies cited by them as evidence for this dry period.

3. Since 3765 BP the level has fallen and risen three times at the scale investigated. High levels occurred approximately every 1300 years as determined by linear interpolation between ^{14}C dates. The two intervening high points had similarity indices of 0.408 and 0.412.

4. The lowest water levels after the two basins were united, around 4500 years BP, centered around 3200, 2200 and 600 years BP. The similarity indices at these three times were 0.191, 0.157, and 0.197 respectively.

5. Since c. 4500 years BP, water levels have not been low enough to reisolate Beauty Bay, nor high enough to put the mouth bar under much more water than at present. The bar is now under one meter of water, so the surface level of the lake has varied less than one meter in elevation for any extended period during this time.

Acknowledgment

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The "New Geology" and its Association with Possible Oil and Gas Accumulations in Wisconsin

Albert B. Dickas

The history of exploration for petroleum in the United States can be subdivided into distinct intervals based upon the prevailing philosophy employed in such exploration. Since the initial discovery of crude oil in the United States among the rolling hills outside Titusville, Pennsylvania, by "Colonel" Edwin Drake in 1859 (Hubbert 1966), the processes of exploration for this commodity have been under continual scrutiny. Numerous scientific, and some decidedly not so scientific, theories regarding the origin, migration, and accumulation of subsurface oil and gas have been advanced. One of the earliest, the concept of "creekology," suggested crude oil was to be found underlying areas of principal surface drainage. The anticlinal theory, advocated by White (1885), associated petroleum accumulation to the upper reaches of rock folded by compressional or other forces.

On the 10th day of the twentieth century, the Spindletop field discovery well was brought in along the Texas Gulf Coast, flowing out of control at the rate of 100,000 barrels of crude oil per day. Immediately wildcatters sought means of effectively identifying subsurface salt-domes, miles-high intrusions of rock salt that seemed to trap oil and gas unlike any other geologic phenomena. Other exploration hypotheses of temporary significance have included low angle (overthrust) displacement belts and anomalously high energy-wave (bright-spot) analysis.

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During the peak of each new orthodoxy, a different geographic sector of the country obtained the prosperity attendant upon the expanding oil and gas industry. For example, the anticlinal theory of exploration was responsible for the expansion of the American oil industry westward from the Keystone state into the Ohio River Valley during the late nineteenth century. Unfortunately this movement never reached Wisconsin. Attempts were made; in fact 56 wells have been drilled since 1865, but all were "dry and abandoned" (Fig. 1). By World War II Wisconsin had been written off, declared lacking in commercial petroleum-discovery potential because the rock strata were considered geologically too old for petroleum generation.

Consistency of change is one of few undeniable absolutes, and it was only a matter of time until a new concept of geologic exploration should focus upon the ancient terranes of Wisconsin, and indeed, did so in Bayfield County in the Autumn of 1983. Agents representing major American corporations began leasing private and public lands for petroleum exploration. During 1984 and 1985, geophysical crews conducted seismic, gravity, and magnetic surveys in northwestern Wisconsin. Why, after a century and a quarter, had these lands become the focus of such costly attention? The answer is to be found in the annals of geologic debate that raged internationally from approximately 1900 until 1966. Two topics are of

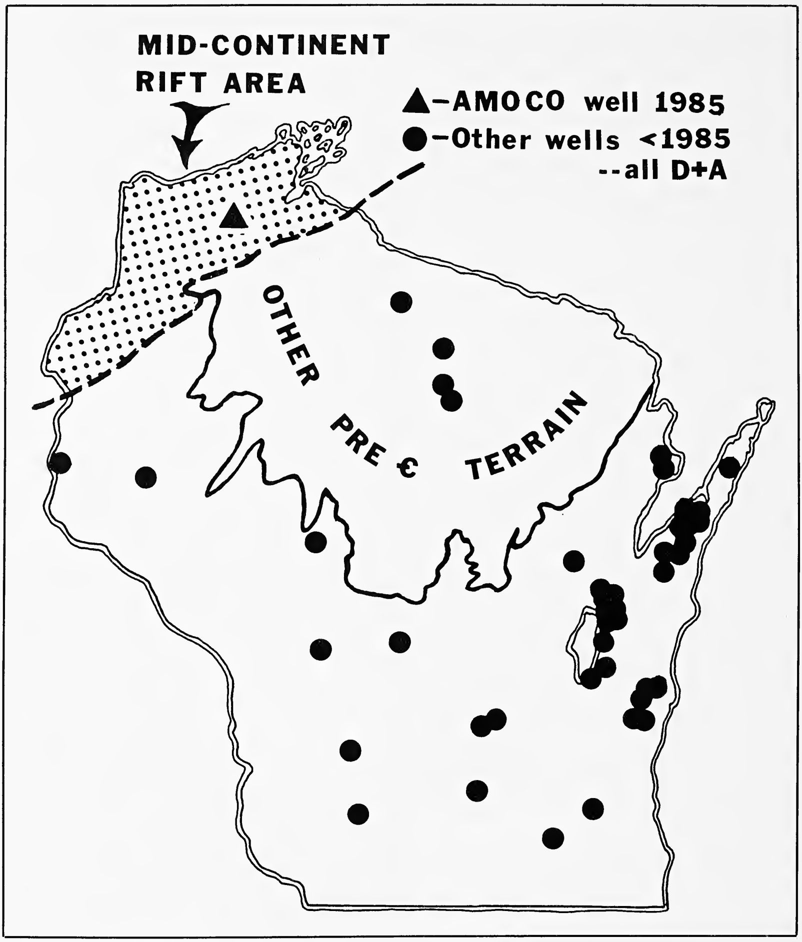

Fig. 1. Wells drilled for oil and/or gas prior to 1985 in Wisconsin. All were declared dry and abandoned by operator.

significance. The first dealt with "solving the mystery of the Earth" (Wood 1985), or more precisely, the identification of forces responsible for first-order surface features—continents, ocean basins, and mountain ranges. The second scientific debate involved the question of when life on Earth originated.

Plate Tectonics

The solution of the great Earth mystery suffered from schismatism. One school of knowledge depended upon a fixist state whereby Earth gradually constructed its surface morphology through periodic vertical movements caused by crustal contraction. In opposition stood the mobilists, arguing for horizontal crustal motion according to the recent discoveries, by Henri Becquerel in 1896 and Pierre and Marie Curie in 1903, of the processes of radioactivity (Eicher 1968). The fixists perceived our planet as dying, with its endowed internal engine gradually slowing as a result of irretrievable conductive loss of heat power. The mobilists argued that conductive loss was being replaced by new heat volumes derived through the newly discovered elemental radioactive decay.

In 1915 Alfred Wegener, a German meteorologist, geophysicist, and explorer of Greenland, published "Die Entstehung der Kontinente und Ozeane" (On the Origin of Continents and Oceans), a unifying theory of earth-crust motion bound by mobilistic concepts of his own derivation. While ultimately silencing the fixist school of thought, this "continental drift" theory over the next several decades became increasingly mired in controversy among geoscientists, physicists, chemists, and mathematicians. Consolidated by opposition status quo defenses of a lack of proof of continental movement and frictional forces of impossible magnitudes, the drift theory slowly lost relevance with the death of Wegener on the Greenland ice-cap in 1930 and the approach of a worldwide depression and war.

In the aftermath of that war, Wegener's ideas were again seriously discussed by geoscientists employing new analysis techniques. The fathometer (depth recorder) and magnetometer (magnetic field analyzer) had been technologically modified and miniaturized early in World War II for anti-submarine surveillance. With the arrival of peace these instruments, along with the ships and aircraft upon which they were mounted, were declared surplus by the military and adopted for use by a generation of fledgling oceanographers unfettered by older scientific theories.

By the late 1950s Maurice Ewing, Bruce Heezen, and Marie Tharp, among many others, working out of the Lamont Doherty Geological Observatory in downstate New York, had gathered sufficient depth data to present an artist's view of the ocean floors (Heezen et al. 1959). Startling in their appearance, these charts for the first time displayed a ridge and rift system, generally occupying a central position that could be traced worldwide from the Indian to the Atlantic to the Pacific Ocean (Fig. 2). Within the next decade, coalescing scientific discoveries began to complete the picture. Previously disjointed masses of paleontological, gravimetric, paleomagnetic, and petrographic data now came together in the minds of physicists, biologists, and geologists as one unified theory. By 1966, the "mystery of the Earth" had been identified, and Wegener had been vindicated in his belief that a precise analysis and understanding of rocks, their structures, and fossils would require very different arrangements of the continents in the past than those of the present (Schwarzbach 1986). In this updated version the phrase "continental drift" had been altered in the best interests of scientific nomenclature to "plate tectonics." Since the mid-1960s plate tectonics has caused a major academic revolution within the earth sciences, with the result that most practicing petroleum geologists have altered their techniques of applied oil and gas exploration.

Life on Earth

The second great development in scientific philosophy important to the commercial oil or gas potential in Wisconsin is the debate on the origin of life on Earth. Rocks outcropping over much of Wisconsin are Precambrian in age; that is, they were deposited in their present position in excess of 570 million years ago. To many geologists, Precambrian rock is seen as

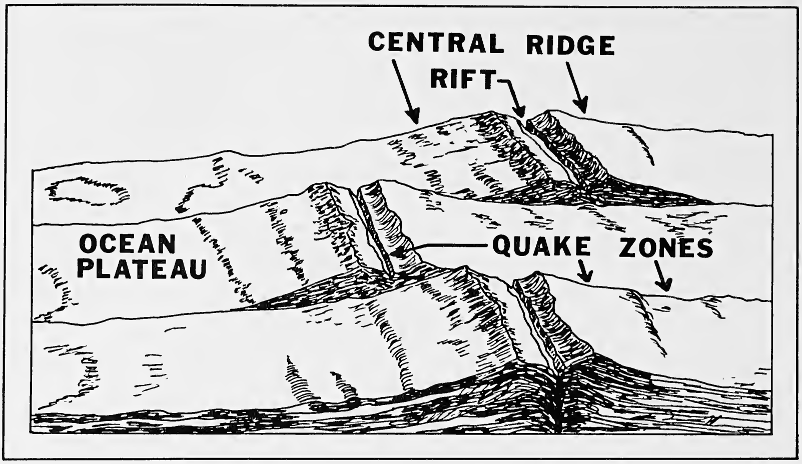

Fig. 2. Artist's view of the topography of the ocean floor showing relative locations of centrally positioned ridge and rift.

the end geologic product of thousands of millennia during which turbulent events created earth environments entirely unfavorable to the ultimate development of petroleum and natural gas. As recently as two decades ago it was believed that prolonged earth movements and periods of rock deformation, both characteristic of the Precambrian era, did not permit the evolution or preservation of life forms. Jones (1956) emphasized this bias by stating that "the recognition of evidence of life in Precambrian strata is one of the most controversial problems in all geology and there is considerable doubt expressed by many paleontologists concerning the nature of the micro-fossils which have been reported." Similar statements aided in the development of anti-early-life philosophies that have been prevalent among many petroleum geologists. However, this early learned bias is rapidly disappearing with the acceptance that the appearance of life was an early development in Earth history and that fossiliferous, organic-rich sedimentary rocks form a significant portion of the Precambrian stratigraphic record (McKirdy 1974). Since the 1950s fossils have been discovered in rock as old as 3.5 billion years in South Africa (Levin 1988), Australia, the Soviet Union, and along the north shore of Lake Superior (Tyler and Barghoorn 1954); it has been shown that this primordial organic material does not differ in any respect from that which is much younger as a potential source material for oil or gas (Fig. 3). The East Siberian Platform (Irkutsk Amphitheater) Petroleum Province, USSR, contains the largest known reservoirs of indigenous Precambrian gas, oil, and condensate (Meyerhoff 1980). More than ten commercial fields have been reported since 1962 from this isolated sector of the Soviet Union, all of which contain at least one reservoir horizon within the Precambrian section (Fig. 4). The oldest of these strata are approximately 925 million years old. In 1963, The Ooraminna #1, a 1861 meter (6,100 feet) test of Precambrian rocks, was drilled in the Amadeus Basin of Australia. While a production test flowed at an uneconomic

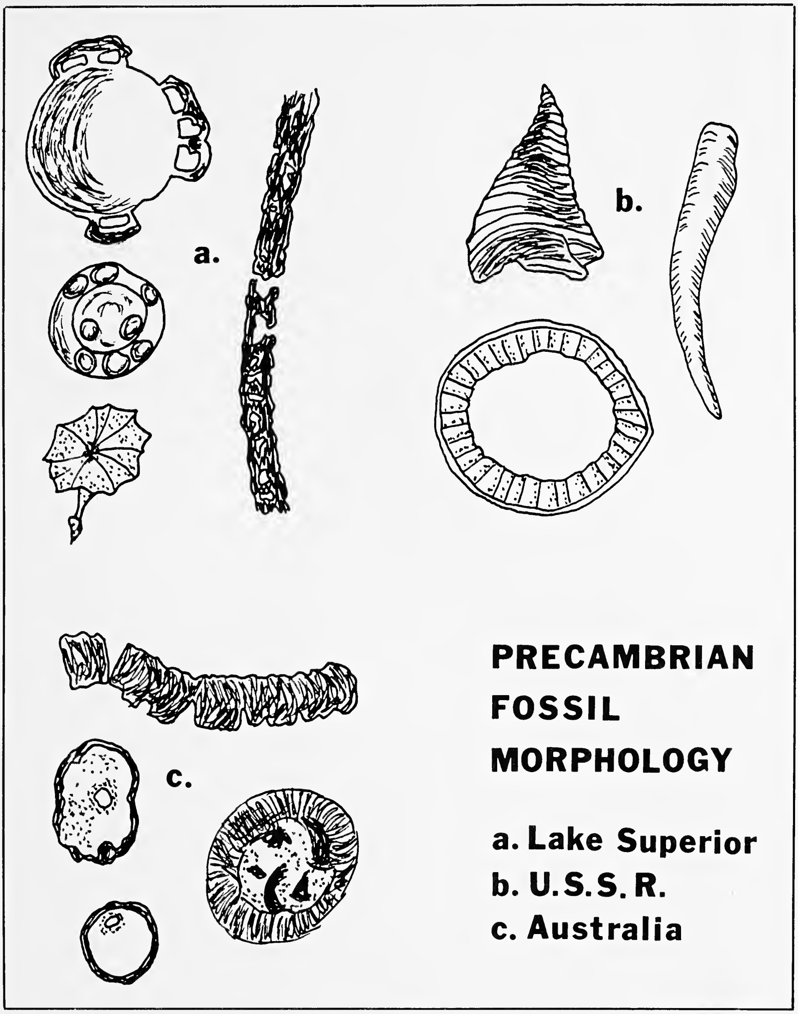

Fig. 3. Examples of fossil morphology from rocks of Precambrian age as collected on three continents. (After Raup and Stanley 1971; Levin 1988).

12,000 cubic feet of natural gas per day, this well was a resounding geologic success as it constituted "irrefutable evidence of indigenous hydrocarbons in the Precambrian of Australia" (Murray et al. 1980). Recent exploratory drilling in Australia discovered "live oil, possibly the oldest oil in the world," in rocks 1.4 billion years of age (Fritz 1987). In 1964, the discovery well for the Weiyuan gas

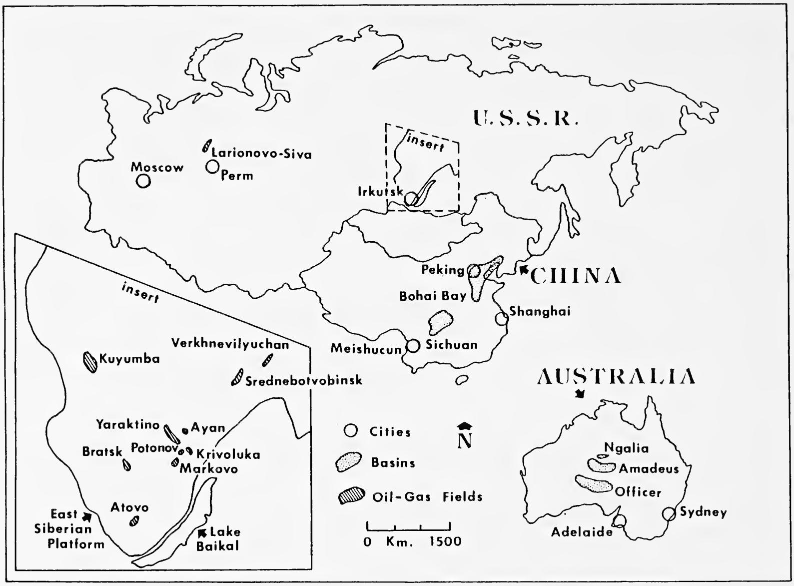

Fig. 4. Commercial oil and/or gas fields in China, Australia, and the USSR in which production is derived from Precambrian-age rocks.

field in the central Sichuan Basin of the People's Republic of China was announced (Fig. 4). Here the principal producing interval lies within the Dengying Formation of Upper Sinean (late Precambrian) age (Shicong et al. 1980).

In the short span of three years during the early 1960s, decades of prejudice against hydrocarbon association with Precambrian strata were overcome. Not only has Precambrian life been generally accepted (Cooper et al. 1986), but so has the economic significance of rift structures created through the dynamics of plate tectonics. Either one or both of these concepts were responsible for the petroleum discoveries in the USSR, Australia, and China. In the early 1980s several entrepreneurs employing these "new geology" concepts as their principal exploratory philosophy began to view northern Wisconsin with enthusiasm. These individuals were interested in the Midcontinent Rift, a geologic structure known principally through geophysical research and considered an ideal field analog to the features formed by extensional plate tectonics.

Midcontinent Rift

The Midcontinent Rift is an ancient crustal scar, first identified in subsurface rocks in northwestern Kansas (Woollard 1943) and traceable by analysis of earth's gravity field for 1,400 kilometers (870 miles) north and east across Iowa, Minnesota, and into northern Wisconsin (Fig. 5). There, the rift trend branches along the north and south shores of Lake Superior. This scar is evidence of Precambrian pressures operating within the mantle of the Earth. These pressures began to divide the early version of the North American continent into two distinct land

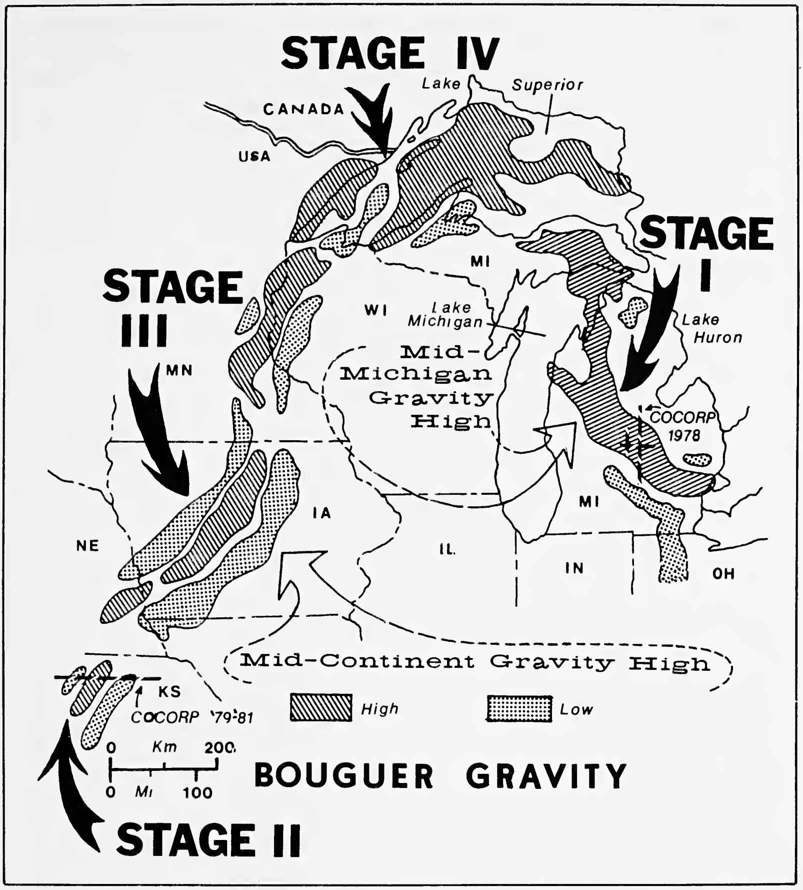

Fig. 5. Trend of the Midcontinent Rift System in the central United States as identified by the Bouguer component of the Earth gravity field. Shown is the geographic extent of the four stages of geologic development which together compose the entirety of the rift (modified from Dickas 1986).

masses. Initiated approximately 1.1 billion years ago, these gigantic tectonic movements increasingly bifurcated the land for some 50 million years. Then, with a maximum separation measuring 60–70 kilometers (40–44 miles), the internal forces dissipated, and the rift gradually healed itself.

While undergoing plate tectonic spasms, the rift served as a conduit for the expulsion of thousands of feet of lava onto the surface of the Earth. These lava fields today can be traced over 100,000 square kilometers (39,000 square miles) of both the north and south shores of Lake Superior (Green 1982). Here, they form the basement upon which younger sedimentary rocks ultimately were deposited. This post-lava series of strata, included in the Keweenawan Supergroup (Morey and Green 1982), is more than 7,600 meters (25,000 feet) thick and can be found outcropping along the river bottoms and shorelines of Douglas, Ashland, and Bayfield counties (Dickas 1985 and 1986). It is this accumulation of sandstone, siltstone, and regionally distributed organic shale, deposited in rifted basins, that has drawn the recent interest of oil and gas explorationists.

A three-dimensional model of the Midcontinent Rift in northern Wisconsin would be constructed of three rectangular slabs, lying side by side (Fig. 6). The central block would be elevated relative to the flank blocks. Initially these slabs would be composed of basaltic (lava) rock. Over the central, or horst block, a lens-shaped volume of lightweight material (sandstone and shale) replaces that portion of the lava rock lost to ancient erosion. The flank blocks are covered rather uniformly by thick layers of similar low density rocks, protected from erosion by their depressed elevation. Finally all three slabs are covered by a thin veneer of unconsolidated sediment representing glacial accumulations of the past several thousand years.

The Rock Character

Rift structures of Precambrian age have been proven to have economic petroleum potential elsewhere in the world, but to date no oil or gas reserves in this country are known to be associated with rift rocks, regardless of their geologic age. While philosophical freedoms allowed by "new geology" theories encouraged explorationists to enter northern Wisconsin in 1983, commercial success in our state will ultimately depend upon the subsur-

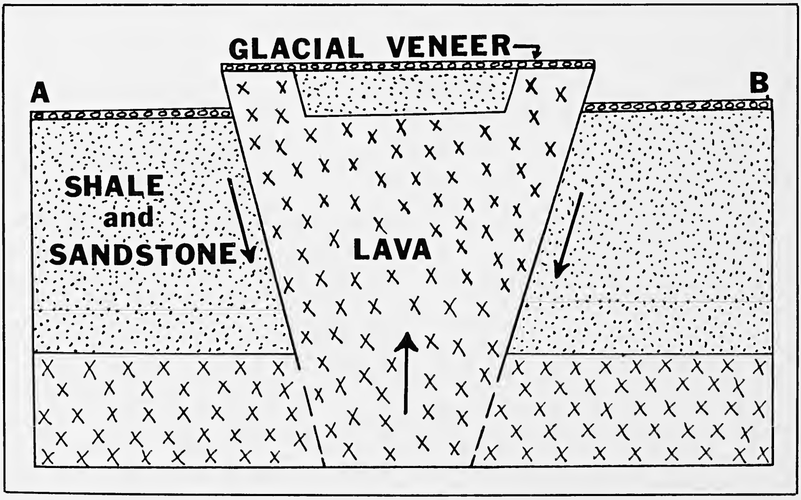

Fig. 6. Cross-sectional model of the Midcontinent Rift for northern Wisconsin. Orientation is A (area of Superior) southeast to B (area of Hayward). Arrows represent relative movement of major geologic blocks.

face physical characteristics of the Keweenawn Supergroup strata.

Such success relies on the presence of three geologic conditions: (1) an organic-rich rock that acts as the source of petroleum; (2) an adjacent and permeable rock that allows concentration of migrating petroleum into an economic accumulation; and (3) another adjacent but impermeable rock that prevents the accumulated petroleum from being lost by migration to the surface. In the vicinity of the Wisconsin-Michigan border a source rock is known. Identified in the 1880s (Irving 1883), the Nonesuch Shale is rich in organic matter and actually drips small quantities of crude oil through the ceiling-rocks of the White Pine copper mine of Michigan's Upper Peninsula. This source rock has been traced westward into the Lake Nebagamon region of Douglas county, Wisconsin, but its presence further southwest along the Midcontinent Rift is a matter of speculation.

The presence in northern Wisconsin of rock capable of pooling and trapping hydrocarbons is also speculative. The primary purpose of the seismic, magnetic, and gravimetric analyses conducted on land during 1984 and offshore Lake Superior during 1985 was to indirectly ascertain and qualify these characteristics.

The Future for Wisconsin

Between the Autumn of 1983 and end of 1985 an estimated four to five million dollars was spent on geological and geophysical evaluation of hydrocarbon potential in northern Wisconsin. A 3,660 meter (12,000 foot) test well was announced by Amoco Production Company (USA) in 1985, to be located in Bayfield County (Fig. 1). Soon after, however, the price of a barrel of crude oil collapsed from $25 to less than $9, placing all drilling programs "on-hold." The American oil and gas industry entered a negative economic cycle that produced unemployment and lowered exploration expenditures to levels not experienced since the great depression of the 1930s. In spite of this unprecedented event, most drilling leases in northern Wisconsin have been maintained by the companies who have established positions in this area, and all are watching the slow, long-term recovery of the price of a barrel of crude oil.

All scientific endeavors require an amount of luck to reach successful conclusions. This is no less true for Wisconsin's potential as an oil or gas-producing state. Should such potential be realized within the next several years, credit must be given to the numerous researchers worldwide who amalgamated the recently developed theories of Precambrian life and rift tectonics into "new geology" philosophies of petroleum exploration.

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Use of Discriminant Analysis to Classify Site Units Based on Soil Properties and Ground Vegetation

John R. Trobaugh and James E. Johnson

Abstract. *Ten forested plots were located in each of three site units in northeastern Wisconsin. The site units selected for study, Padus, Pence, and Vilas, reflect a range in productivity from high to low based on soil-site equations for red pine (*Pinus resinosa *Ait.). Soil physical and chemical properties and percent frequency of ground flora were used as independent variables in a canonical discriminant analysis to separate the site units. The percent correct classifications were as follows: soil variables only, 67%; vegetation variables only, 57%; soil and vegetation variables 83%. The strongest soil discriminator variables generally reflected finer textures and higher nutrient content associated with the Padus units, while the strongest vegetative discriminators indicated either the more mesic, nutrient rich Padus sites (*Viola *spp.,* Polygonatum biforum *(Walt.) Ell., and* Dryopteris spinulosa [*O.F. Mull.*] *Watt.) or the dry, acidic Vilas sites* (Gaultheria procumbens *L.,* Vaccinium angustifolium *Ait., and* Waldsteinia fragarioides [*Michx.*] *Tratt.).*

Classification of forest land into distinct units is currently an important area of research and development in the U.S. Two recent symposia (Bockheim 1984, Wickware and Stevens 1986) have included numerous papers dealing with the development of classification systems and associated methodologies. Systems in common use in the U.S. include single factor systems such as soil surveys (Arnold 1984) and habitat typing (Kotar and Coffman 1984), and multifactor systems such as ecological forest site classification that considers climate, geology/parent material, physiography, soils, and vegetation (Barnes et al. 1982).

An important aspect of land classification is that the site units must be recognizable on the landscape and must represent somewhat homogeneous soil and vegetation conditions. In order to be useful for management purposes the units must also reflect differences in productivity and management interpretations (Barnes et al. 1982).

Both the single and multifactor approach are being used in forested areas of Wisconsin. In order for these systems to reflect differences in productivity and management interpretations, studies are needed to determine the amount of variation within site units. This study was established to determine (1) the variation among soil properties and ground vegetation within site units and (2) the importance of these variables in discriminating among three common site classification units in northeastern Wisconsin.

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Methods

Study Area

The study area was located in Oneida and Forest Counties, Wisconsin (Fig. 1). This area is located within a single homogeneous macroclimatic zone (Rauscher 1984), with the following climatic features: average annual maximum temperature 11.2°C, average annual minimum temperature −0.6°C, average frost free season from 87 to 117 days, average annual precipitation 782 mm with 60% falling during the growing season, and an average annual snowfall of 1,397 mm.

Throughout the study area the bedrock is undifferentiated crystalline rock of pre-Cambrian age, overlain by glacial drift deposited during the Woodfordian Substage of the Pleistocene. Most of the glacial deposits are sorted, stratified, glaciofluvial sand and gravel. The topography is primarily pitted and unpitted outwash; however, study plots were generally located on level landscape positions.

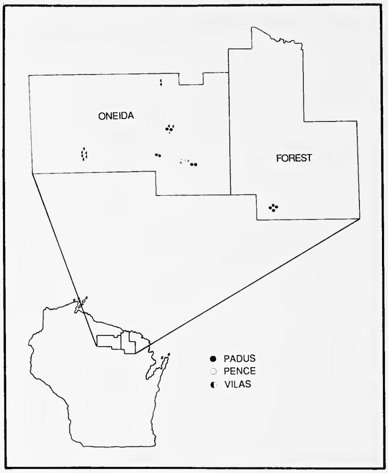

Fig. 1. Study area in northeastern Wisconsin.

Site Units

The forest land classification units selected in this study were generally defined as site units and are similar to the Ecological Land Types (ELT's) used by the Nicolet National Forest (Nicolet National Forest 1983). These site units have similar landform and climatic conditions, but differ in soil and vegetation features. The three site units were all located on glacial outwash plains or uplands within the two county study area. The site units, named for the predominant soil series found in each, have the following features:

Site Unit	*Soil Series*	*Soil Taxonomic Classification*	*Habitat Type (Kotar 1986)*
Padus	Padus	Alfic Haplorthod (coarse-loamy, mixed, frigid)	*Tsuga-Maianthemum*
Pence	Pence	Entic Haplorthod (sandy, mixed, frigid)	*Tsuga-Maianthemum-Vaccinium*
Vilas	Vilas	Entic Haplorthod (sandy, mixed, frigid)	*Acer-Quercus-Vaccinium*

These site units represent a range of site productivity from high (Padus) to low (Vilas) as follows:

Site Unit	*Mean Red Pine Soil-Site Index Alban (1976)*	*Standard Deviation of Soil-Site Index*
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Padus	18.4	0.9
Pence	16.7	0.4
Vilas	16.5	0.4

All three are especially important throughout the study area because they are commonly converted from the existing cover type to pine plantations. The level landscapes and sandy soil textures generally make these site units well-suited for site conversion and pine plantation management.

Field Methods

During the summer of 1984 ten Padus, ten Pence, and ten Vilas site units were identified within the study area. Within each unit a circular 100 m^2 plot was located, and all trees greater than 12.7 cm in dbh were tallied by species, dbh, and height. On a nested 25 m^2 plot all trees between 2.5 cm and 12.7 cm dbh were recorded by species. On a nested 4 m^2 plot all woody stems less than 2.5 cm dbh and 1 m in height were recorded by species and percent canopy cover. Woody vegetation measured on these plots roughly corresponded to the overstory, upper understory, and lower understory strata. On 12 systematically located 1 m^2 plots all ground herbaceous and woody vegetation (less than 1 m tall) was recorded by species, and percent frequency was calculated.

Adjacent to each 100 m^2 plot a 1 by 1.5 m soil pit was dug to the C horizon. A complete field description was conducted, including horizon designation, horizon depth, color, texture, structure, pH, mottle identification, and consistence. Soil samples from each horizon were collected from the soil pit and from four additional auger samples taken near the plot. These five samples were then composited into a single sample for the plot. Four forest floor samples were collected from the vicinity of the pit. These samples were separated into Oi + Oe and Oa horizons and then composited by horizon.

Lab Methods

All soil samples were air-dried, ground to pass a 2-mm sieve, and subjected to the following physical and chemical analyses: 1) particle size analysis using the hydrometer method (Day 1965), 2) total nitrogen using micro-Kjeldahl (Bremner 1965), 3) available phosphorus using the ammonium molybdate method following extraction in 0.025N HC1 and 0.03N NH_4F, 4) the same extract was used to determine available potassium using a flame photometer following the same extraction procedure as for P, 5) exchangeable calcium and magnesium by flame photometry following extraction in 1N NH_4OAc (Liegel et al. 1980), 6) pH using a glass electrode with 7.5 g soil in 10 ml of distilled water, 7) organic matter content using the Walkley-Black method (Walkley and Black 1934), and 8) buffer pH using the method of Shoemaker et al. (1961).

Forest floor samples were dried to a constant weight at 65°C. Samples were then weighed and ground to pass a 1-mm sieve. Total nitrogen was determined using micro-Kjeldahl (Bremner 1965), and total phosphorus, potassium, calcium, and magnesium were determined using an ARL plasma emission spectrophotometer following digestion in concentrated nitric and perchloric acid (Liegel et al. 1980).

Statistical Analysis

The three site units were used as qualitative groups and suites of 53 soil variables and 60 ground vegetation species were used as discriminator variables in a canonical discriminant analysis (Klecka 1980). Variables considered to be independent were selected for analysis. The analysis was conducted using the soil variables, vegetation variables, and the two combined. The jackknife method was used to determine the percentage of correct classification following each discriminant analysis. The jackknife method is recommended when sampled size is small relative to the number of variables (Lachenbruch and Mickey 1968). Using this method, one plot at a time was withheld from the data set, and the discriminant function was derived from the remaining 29 plots. Independent variables from the withheld plot were used to calculate the site unit classification. This procedure was repeated for each of the 30 plots, and the percent correct classification was determined.

Analysis of variance and mean separation using the Sheffe test at the 0.05 probability level were used to determine significant differences between the soil and vegetation discriminator variables.

Results and Discussion

Site Unit Vegetation

All plots located on the three site units were forested (Table 1), with pines, aspen-birch, spruce-fir, and red maple (*Acer rubrum* L.) predominating in the overstory. The plots on the Pence site units had the highest basal area and number of stems/ha, followed by the Padus and Vilas site units. The upper understory, however, was densest on the Padus site units, followed by the Vilas and Pence site units (Table 2). The lower understory was dominated on all site units by beaked hazel (*Corylus cornuta* Marsh.), but was densest on the Vilas site units (Table 3). Curtis (1959) identified beaked hazel as the most common shrub species in the northern mesic forests of Wisconsin, and is commonly considered a strong competitor to tree regeneration in these stands (Buckman 1964).

Site Unit Soil and Forest Floor Properties

Soil physical and chemical properties for representative profiles from each of the site units are shown in Table 4. The Padus soils tended to be finer-textured and higher in nutrient content than the Pence and Vilas soils. In general, the Padus site units reflect soil conditions typical of Curtis' (1959) northern mesic forest, the Pence site units are typical of the northern mesic/dry-mesic forest, and Vilas site units are typical of the dry-

Table 1. Mean overstory number of stems/ha, basal area/ha, and dominant species of second-growth forests on three site units in northeastern Wisconsin.

Site Unit	Age	No. Stems/ha		Basal area (m^2/ha)		
	yrs.	$\bar{X}$	SD	$\bar{X}$	SD	Dominant Species
Padus	60	770	337	23.8	7.4	*Acer rubrum* L. *Betula papyrifera* Marsh. *Pinus resinosa* Ait.
Pence	63	840	365	33.1	10.7	*Betula papyrifera* Marsh. *Populus grandidentata* Michx. *Abies balsamea* (L.) Mill. *Pinus resinosa* Ait. *Picea glauca* (Moench) Voss
Vilas	60	580	344	24.7	11.7	*Pinus strobus* L. *Pinus resinosa* Ait. *Quercus rubra* L. *Populus tremuloides* Michx. *Pinus banksiana* Lamb.

$\bar{X}$ = Arithmetic mean SD = Standard deviation

Table 2. Mean upper understory number of stems/ha, basal area/ha, and dominant species of second-growth forests on three site units in northeastern Wisconsin.

Site Unit	*No. stems/ha*		*Basal area (m^2/ha)*		
	$\bar{X}$	*SD*	$\bar{X}$	*SD*	*Dominant Species*
Padus	1160	573	4.6	3.6	*Betula papyrifera* Marsh. *Acer rubrum* L. *Acer saccharum* Marsh. *Abies balsamea* (L.) Mill
Pence	680	672	3.5	1.8	*Abies balsamea* (L.) Mill *Picea mariana* (Mill.) B.S.P. *Betula papyrifera* Marsh. *Picea glauca* (Moench) Voss *Prunus serotina* Ehrh.
Vilas	720	460	2.6	2.1	*Abies balsamea* (L.) Mill *Acer rubrum* L. *Acer saccharum* Marsh. *Populus tremuloides* Michx. *Pinus banksiana* Lamb.

$\bar{X}$ = Arithmetic mean SD = Standard deviation

Table 3. Mean lower understory number of stems/ha, percent canopy cover, and dominant species of second-growth forests on three site units in northeastern Wisconsin.

Site Unit	*No. stems/ha*		*Canopy Cover (%)*		
	$\bar{X}$	*SD*	$\bar{X}$	*SD*	*Dominant Species*
Padus	7,500	6,435	25	16	*Corylus cornuta* Marsh. *Acer saccharum* Marsh. *Abies balsamea* (L.) Mill.
Pence	6,500	6,519	21	19	*Corylus cornuta* Marsh. *Prunus virginiana* L. *Abies balsamea* L. Mill.
Vilas	19,750	26,655	34	39	*Corylus cornuta* Marsh. *Abies balsamea* (L.) Mill. *Amelanchier arborea* (Michx. f.) Fern

$\bar{X}$ = Arithmetic mean SD = Standard deviation

Table 4. Soil physical and chemical properties from plots representing typical features of the Padus, Pence, and Vilas site units in northeastern Wisconsin.

					Texture			Bulk	Nutrient Content (kg/ha)					Organic	
Site Unit	Plot	Horizon	Depth (cm)	Color	% sand	% silt	% clay	Density g/cm³	N	P	K	Ca	Mg	Matter (t/ha)	pH
Padus	15	E	0-9	7.5YR 4/2	71	22	7	1.3	1,708	95	52	8.4	1.9	33.1	5.1
		Bhs	9-23	7.5YR 3/4	83	6	11	1.0	564	235	50	7.4	2.0	29.5	5.1
		Bs + Bt	23-54	10YR 4/4	59	31	10	1.0	894	304	153	14.4	4.3	47.9	5.1
											(mg/kg)			%	
		C	54 +	7.5YR 4/4	87	6	7	1.1	100	40	30	30	0.5	0.8	5.0
Pence	29	E	0-5	7.5YR 4/2	82	13	5	1.4	206	5	26	0.9	0.3	11.0	4.1
		Bhs	5-21	7.5YR 3/4	81	11	8	1.6	1,851	69	222	3.2	1.3	73.5	4.7
		Bs	21-42	7.5YR 4/4	87	8	5	1.6	466	98	125	1.7	1.7	30.0	4.9
											(mg/kg)			%	
		C	42 +	7.5YR 4/6	89	6	5	1.2	90	47	38	0.8	0.5	0.7	5.2
Vilas	26	E	0-4	5YR 3/2	85	10	5	1.1	267	5	20	0.6	0.5	13.1	4.3
		Bhs	4-17	7.5 YR 3/4	86	7	7	1.5	734	77	77	1.0	1.9	40.6	4.9
		Bs	17-42	7.5YR 4/6	89	5	6	1.5	670	259	118	1.9	2.8	33.5	5.0
											(mg/kg)			%	
		C	42 +	10YR 4/4	95	1	4	1.6	40	75	20	0.5	0.8	0.4	5.2

Table 5. Forest floor dry weight, depth, and nutrient content from plots representing typical features of the Padus, Pence, and Vilas site units in northeastern Wisconsin

Site Unit	Plot	Horizon	Depth (cm)	Dry wt. (t/ha)	Nutrient Content (kg/ha) N	P	K	Ca	Mg
Padus	15	Oi + Oe	1	6.6	125	11	11	120	12
		Oa	5	69.6	401	47	52	278	118
		Total	6	76.2	526	58	63	398	130
Pence	29	Oi + Oe	1	7.3	72	6	8	52	6
		Oa	3	95.7	490	44	69	230	56
		Total	4	103.0	562	50	77	282	62
Vilas	26	Oi + Oe	1	8.0	117	9	10	79	11
		Oa	3	57.0	477	38	56	208	56
		Total	4	65.0	594	47	66	287	67

mesic/xeric forest. The forest floor physical and chemical properties for representative site units are shown in Table 5. The Pence site unit had the forest floor with the greatest dry weight, but was largely intermediate in nutrient content. The Padus forest floor had the greatest P, Ca, and Mg, while the Pence forest floor had the greatest K and the Vilas had the greatest N.

Discriminant Analysis

The discriminant analysis resulted in three functions, one based on soil properties, one based on ground vegetation frequency, and one based on a combination of soil and vegetation variables. For site units to be considered useful, they must represent unique features of landforms, soils, or vegetation, or must have distinct management interpretations (Moon 1984). In this analysis common soil properties considered part of routine soil analysis and the existing ground vegetation were found to be effective in distinguishing among the three site units. This procedure was also useful in separating site units in Michigan, where a suite of eight soil and topographic variables and nine vegetation variables discriminated between 11 upland forest ecosystems on the McCormick Experimental Forest (Pregitzer and Barnes 1984).

The soil, vegetation frequency, and combined variables used in the discriminant analysis are presented in Tables 6–8. The 21 site, soil, and forest floor variables (Table 6) reflect a combination of physical and chemical properties, the most important of which is the soil-site index (Alban 1976). This value represents the calculated red pine site index based upon soil texture, depth, and the presence of fine-texture bands that may significantly influence tree growth (Hannah and Zahner 1970). It indicates a significant difference between the Padus and Pence site units but not between the Pence and Vilas. In general, the finer soil textures associated with the Padus site unit, coupled with higher soil and/or forest floor P, K, Ca, and Mg, resulted in strong discrimination between the Padus and other site units. Using the jackknife validation procedure, the predicted site unit membership was as follows: Padus, 80%; Pence, 50%; and Vilas, 70%, for an overall correct classification of 67%.

The presence of key species of vegetation have been shown to be strong indicators of edaphic factors in forest ecosystems (Pregitzer and Barnes 1982)

Table 6. Means, standard deviations (in parentheses), and F statistics for site and soil discriminator variables presented in order of stepwise inclusion for the Padus, Pence, and Vilas site units in northeastern Wisconsin.

Variables	*F Prob.*	*Padus*	*Pence*	*Vilas*
Red Pine				
Site Index (m)	0.0000	18.4 (0.9) a[1]	16.7 (0.4) b	16.5 (0.4) b
% Clay, E Horizon	0.0043	8.2 (2.8) a	6.3 (1.1) ab	5.2 (1.0) b
Mg, Oa Layer (kg/ha)	0.0062	85.4 (25.7) ab	105.1 (42.3) a	58.2 (15.6) b
pH, Bhs Horizon	0.0016	5.1 (0.1) a	4.8 (0.2) b	4.9 (0.1) b
K, Oi Layer (kg/ha)	0.3422	14.0 (4.3) a	11.7 (3.3) a	12.9 (3.0) a
Depth, Bs Horizon (cm)	0.0063	35.8 (12.0) a	25.4 (9.2) ab	20.9 (7.5) b
Depth, Bhs Horizon (cm)	0.7660	15.3 (5.5) a	15.8 (6.7) a	14.0 (4.5) a
% Clay, C Horizon	0.0041	7.4 (3.2) a	5.5 (1.3) ab	4.0 (0.9) b
SMP, Bhs Horizon	0.4634	62.4 (2.2) a	61.5 (1.6) a	62.3 (1.3) a
SMP, E Horizon	0.0093	66.5 (1.3) a	65.4 (1.5) ab	64.4 (1.4) b
P, Bhs Horizon (kg/ha)	0.9556	173.9 (133.5) a	153.2 (170.7) a	158.4 (173.3) a
% Silt, Bs Horizon	0.0000	29.8 (13.3) a	17.3 (7.0) b	8.1 (2.4) b
P, Oi Layer (kg/ha)	0.1391	12.2 (4.1) a	9.2 (2.9) a	10.5 (2.4) a
Ca, Oa Layer (kg/ha)	0.0088	360.9 (160.4) a	339.0 (93.1) a	205.7 (55.0) b
P, E Horizon (kg/ha)	0.0571	35.4 (29.0) a	19.3 (23.0) a	11.3 (6.1) a
Mg, Oi Layer (kg/ha)	0.2921	27.9 (43.8) a	11.3 (5.3) a	12.9 (2.9) a
SMP, Bs Horizon (kg/ha)	0.2998	64.5 (1.4) a	64.2 (0.9) a	65.1 (1.5) a
pH, C Horizon	0.0375	5.1 (1.2) a	5.1 (1.9) a	5.2 (1.4) a
P, C Horizon (ppm)	0.0268	34.3 (13.3) a	55.8 (28.3) ab	64.0 (27.0) b
OM, E Horizon (t/ha)	0.1546	24.9 (18.4) a	14.2 (7.3) a	18.2 (6.5) a
K, Oa Layer (kg/ha)	0.0188	65.2 (15.1) ab	72.8 (14.5) a	53.9 (11.8) b

[1] Means within a row followed by the same letter are not significantly different at the 0.05 level using the Scheffe test.

and have been widely used in developing a habitat type system for use in northern Michigan and Wisconsin (Coffman and Hall 1976, Kotar 1986). The percent frequency of the important discriminating species (Table 7) indicate that *Gaultheria procumbens* L., *Vaccinium angustifolium* Ait., *Corylus cornuta* Marsh., and *Waldsteinia fragarioides* (Michx.) Tratt. are all strong discriminators of the Vilas site unit. The more productive Padus site is discriminated by *Polygonatum biforum* (Walt.) Ell. and *Dryopteris spinulosa* (O.F. Mull.) Watt. The Pence site unit is generally intermediate; however, *Prenanthes alba* L., *Clematis virginiana* L., and *Lycopodium lucidulum* Michx. were found only on the Pence site units. Of these indicator species, only *Vaccinium* was identified by Pregitzer and Barnes (1982) as being a key indicator on the McCormick Experimental Forest in Upper Michigan. The jackknife validation procedure resulted in an overall 57% correct classification, with 60% of the Padus site units correctly classified, 10% of the Pence units correctly classified, and 100% of the Vilas units correctly classified.

The combined soil and vegetative discriminator variables are presented in Table 8. Combining these variables increased the classification percentage to 83, with 90% of the Padus units, 70% of the Pence units, and 90% of the Vilas units correctly classified. The soil and forest floor variables generally reflect the finer textures and higher nutrient content of the Padus and Pence site units, and the higher organic matter content of the Padus units. The vegetative species differ

Table 7. Means, standard deviations (in parentheses), and F statistics for vegetation discriminator variables presented in order of stepwise inclusion for the Padus, Pence, and Vilas site units in northeastern Wisconsin.

Variable (% Frequency)	*F Prob.*	*Padus*	*Pence*	*Vilas*
Gaultheria procumbens L.	0.0000	0.8 (2.6) a[1]	18.3 (24.2) a	70.0 (9.2) b
Vaccinium angustifolium Ait.	0.0000	5.0 (10.5) a	25.0 (25.5) a	65.0 (29.1) b
Lycopodium obscurum L.	0.3742	45.0 (42.7) a	36.7 (40.3) a	21.7 (25.8) a
Polygonatum biforum (Walt.) Ell.	0.0137	16.7 (18.0) a	1.7 (3.5) b	3.3 (8.1) ab
Aster macrophyllus L.	0.2424	80.0 (15.3) a	75.8 (22.4) a	59.2 (41.3) a
Prenanthes alba L.	0.1248	0.0 (0.0) a	1.7 (3.5) a	0.0 (0.0) a
Corylus cornuta Marsh.	0.0976	40.8 (25.3) a	35.0 (29.1) a	61.7 (28.9) a
Dryopteris spinulosa (O.F. Mull.) Watt.	0.2998	2.4 (5.6) a	0.8 (2.6) a	0.0 (0.0) a
Coptis trifolia (L.) Salisb.	0.4046	2.5 (7.9) a	3.3 (5.8) a	0.0 (0.0) a
Fragaria virginiana Duchesne.	0.1553	13.3 (15.3) a	25.0 (25.1) a	8.3 (15.2) a
Streptopus roseus Michx.	0.8473	1.7 (5.3) a	0.8 (2.6) a	0.8 (2.6) a
Waldsteinia fragarioides (Michx.) Tratt.	0.0103	0.8 (2.6) a	18.3 (38.7) ab	51.7 (46.6) b
Antennaria neglecta Grenne.	0.3811	0.0 (0.0) a	0.0 (0.0) a	0.8 (2.6) a
Clematis virginiana L.	0.3811	0.0 (0.0) a	0.8 (2.6) a	0.0 (0.0) a
Actaea alba (L.) Mill.	0.3811	0.8 (2.6) a	0.0 (0.0) a	0.0 (0.0) a
Linnaea borealis L.	0.1979	1.7 (5.3) a	10.8 (21.2) a	15.8 (20.6) a
Woodland grass	0.2844	90.0 (15.6) a	88.3 (27.6) a	75.8 (19.0) a
Lycopodium lucidulum Michx.	0.3811	0.0 (0.0) a	2.5 (7.9) a	0.0 (0.0) a
Rubus spp.	0.4179	16.7 (24.2) a	32.5 (28.5) a	31.7 (35.3) a
Myrica asplenifolia L.	0.0777	0.0 (0.0) a	0.0 (0.0) a	8.3 (15.7) a
Pyrola virens Schweigg.	0.6120	0.8 (2.6) a	0.8 (2.6) a	0.0 (0.0) a

[1] Means within a row followed by the same letter are not significantly different at the 0.05 level using the Scheffe test.

somewhat from those of Table 7. *Melampyrum lineare* Desr. and *Antennaria neglecta* Grenne. emerged as good discriminators for the Vilas units and *Viola* spp. for the Padus site units.

Conclusion

The development of usable forest site classification systems for large land ownerships is an important area of research. Multiple factor systems based on landform and climate, soils, and vegetation appear to be emerging as superior to the traditional single-factor approaches such as the soil survey. The usefulness of understory vegetative indicators to account for soil differences (Carleton et al. 1985, Pregitzer and Barnes 1982) makes those systems based on ground vegetation desirable. For forestry purposes it is also important that the defined units in the classification system be distinct in terms of site productivity and management interpretations.

In this study three site units from a two-county area in northeastern Wisconsin were subjected to a discriminant analysis based on groups of independent soil and vegetation variables. The strongest analysis, based on 11 soil and 12 vegetative variables, resulted in an overall correct classification of 83%. The Padus, Pence, and Vilas site units are distinct entities, separable in the field based upon soil and vegetative features, and have important soil physical and chemical property differences that readily separate the units when subjected to a stepwise discriminant analysis.

Table 8. Means, standard deviations (in parentheses), and F statistics for site, soil, and vegetation discriminator variables presented in order of stepwise inclusion for the Padus, Pence, and Vilas site units in northeastern Wisconsin.

Variable	*F Prob.*	*Padus*	*Pence*	*Vilas*
Red Pine				
Site Index (m)	0.0000	18.4 (0.9) a[1]	16.7 (0.4) b	16.5 (0.4) b
% Clay, E Horizon	0.0043	8.2 (2.8) a	6.3 (1.1) ab	5.2 (1.0) b
Viola spp.	0.0007	42.5 (19.4) a	36.7 (24.0) a	5.8 (15.7) b
K, Oi Layer (kg/ha)	0.3422	14.0 (4.3) a	11.7 (3.3) a	12.9 (3.0) a
Lonicera canadensis Marsh.	0.2233	1.7 (3.5) a	7.5 (10.7) a	4.2 (5.9) a
K, Oa Layer (kg/ha)	0.0188	64.2 (15.1) ab	72.8 (14.5) a	53.9 (11.8) b
pH, Bhs Horizon	0.0016	5.1 (0.1) a	4.8 (0.2) b	4.9 (0.1) b
Antennaria neglecta Grenne.	0.3811	0.0 (0.0) a	0.0 (0.0) a	0.8 (2.6) a
Corylus cornuta Marsh.	0.0976	40.8 (25.3) a	35.0 (29.1) a	61.7 (28.9) a
Lycopodium obscurum L.	0.3742	45.0 (42.7) a	36.7 (40.3) a	21.7 (24.8) a
Polygonatum biforum (Walt.) Ell.	0.0137	16.7 (18.0) a	1.7 (3.5) b	3.3 (8.1) ab
Depth, Bs Horizon (cm)	0.0063	35.8 (12.0) a	25.4 (9.2) ab	20.9 (7.5) a
Diervilla lonicera Mill.	0.1872	3.3 (7.0) a	18.3 (21.8) a	17.5 (25.9) a
Cornus canadensis L.	0.1781	11.7 (20.9) a	40.0 (37.2) a	28.3 (38.5) a
K, Bhs Horizon (kg/ha)	0.2341	88.7 (47.3) a	92.9 (63.5) a	58.9 (21.7) a
Apocynum androsaemifolium L.	0.0606	0.0 (0.0) a	0.0 (0.0) a	5.0 (9.0) a
Streptopus roseus Michx.	0.8473	1.7 (5.3) a	0.8 (2.6) a	0.8 (2.6) a
OM, E Horizon (t/ha)	0.1546	24.9 (18.4) a	14.2 (7.3) a	18.2 (6.5) a
pH, C Horizon	0.0375	5.1 (0.1) a	5.1 (0.2) a	5.2 (0.1) a
Adiantum pedatum L.	0.3811	0.8 (2.6) a	0.0 (0.0) a	0.0 (0.0) a
OM, Bs Horizon (t/ha)	0.0239	52.2 (14.0) a	44.9 (16.9) ab	33.1 (12.7) b
% Silt, C Horizon	0.2431	9.9 (5.7) a	8.4 (6.3) a	5.6 (5.1) a
Melampyrum lineare Desr.	0.2456	0.0 (0.0) a	0.8 (2.6) a	11.7 (29.2) a

[1] Means within a row followed by the same letter are not significantly different at the 0.05 level using the Scheffe test.

Of the 23 discriminating variables listed in Table 8, 11 are soil or site variables, and 12 are vegetative variables. Calculated site index, an integrated site variable, was the most significant. Soil variables that were important included physical properties such as depth and texture, and chemical properties such as fertility (potassium content), organic matter content, and pH. Important vegetative discriminators included *Viola* spp., *Polygonatum biforum, Corylus cornuta,* and *Apocynum androsaemifolium.*

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TRANSACTIONS

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Contents

It is commonly agreed that Flannery O'Connor placed great importance upon details in fiction. In light of this, it is somewhat surprising that critics have generally ignored the evocative details in O'Connor's own fiction. Emmett argues that statement comes from detail and that detail provides the "intellectual meaning of a book." The final scene in this story cannot be accounted for until we account for the vivid details that precede it.

The population of both the Painted and the Blanding turtle was studied over a six year period. The populations were compared to those found in Michigan, Minnesota, and Missouri. The study, particularly of the Blanding turtle, indicates that habitat should be set aside to preserve populations of this species.

Common whites were white nonslaveholders and small slaveholders who were perceived by themselves and others as not being members of the society's political, social, or economic elites. Many scholars have ascribed to the common whites a harsh racism born out of a fear of competition. And it is widely assumed among historians that this racism cemented loyalties to the slaveholders and led the common whites into the Civil War in order to preserve slavery. Professor Cecil-Fronsman challenges many of the commonly accepted conclusions in this incisive study of common whites and blacks.

A good understanding of population fluctuations in *P. leucopus* has been hampered by a lack of a long-term study. This paper reports the results of a twenty-two year study based on live trapping. The magnitude of the population fluctuations and whether these fluctuations were regular or cyclic were studied.

The Aquatic Macrophyte Community of Black Earth Creek, Wisconsin: 1981–1986 101
John D. Madsen

The biomass and relative species abundance of the submersed aquatic macrophyte communities in Black Earth Creek, Wisconsin, were examined in 1986 and compared to data gathered in 1981 and 1985. The study indicates that although total macrophyte biomass and abundance may fluctuate dramatically due to physical events, the relative frequency and dominance of species remain relatively constant.

Announcement

The Wisconsin Arts Board has awarded the Academy a grant to help publish an anthology of contemporary Wisconsin poetry as a special edition of *Transactions*. There has not been such an anthology for over thirty years, and we think this work will serve as both a showcase and a historical record of the broad geographical, ethnic, and stylistic cross-section of Wisconsin poetry.

Poets who are interested in additional information and directions for submitting poetry should write to the Editor. Since work will be underway before this announcement is published, authors should not delay their inquiries.

From the Editor

We are pleased to be able to publish the 1989 issue of *Transactions* (Vol. 77) in the year of its date. During the past two years we have worked to shift the publication time from February to the fall; it now appears that this distribution schedule can be maintained. Work has already begun on Volume 78 (1990), and Wisconsin writers and people writing about Wisconsin are invited to submit articles or proposals for publication.

The poetry and photography sections contained in the 1988 volume have been well received by members of the Academy. And we are pleased to include another selection of poetry from some of Wisconsin's noted poets in this issue. Though there is no photography section in the current volume, it is hoped that 1990 will see a return of that feature. Anyone wishing to submit a proposal for photography is asked to contact the editor.

Readers of this issue of *Transactions* will see great variety in subjects. Papers range from the concluding one in the series on Black Earth Creek to an analysis of Wisconsin's Changing Dairy Industry to a study of common whites and blacks in Antebellum North Carolina. The opening article, however, is based on a paper presented at the 1988 annual meeting held in Menomonie. The subject of the relationship of photography to memory is common, but David Graham introduces us to "Whittling Time: Photography and the Poetry of Memory." Those who attended the 1989 annual meeting in Green Bay will recognize that this topic was the basis of a symposium presented by three of Wisconsin's leading poets and one of its leading photographers.

In addition to the diversity in the articles presented, I am particularly impressed with the high quality of the work done by people who live in or write about Wisconsin. Making *Transactions* reflect the vigorous intellectual life in the sciences, arts, and letters in our state has been the goal of the Wisconsin Academy for over a hundred years, and it is hoped that the current issue of the journal continues that long tradition.

Comments, submission, or suggestions should be addressed to the Editor.

Carl N. Haywood

Whittling Time: Photography and the Poetry of Memory

David Graham

My subject is, from one perspective, entirely traditional. The link between photography and poetry can be expressed in the most ancient terms: both are children of Zeus and Mnemosyne. The goddess of memory, Mnemosyne, as mother of the Muses, is naturally the source of all the arts and sciences, traditionally defined. Poetry's kinship to memory requires little elaboration; the Greeks delegated authority for poetry to three of Mnemosyne's nine daughters: Calliope, Erato, and Polyhymnia (representing epic, lyric, and sacred poetry, respectively). Photography, which aims to stop time and preserve the present into the future, is, if anything, even more closely allied to memory. The Muse of photography is most likely Clio, the Muse of history, for history is photography's subject and medium.

From another perspective, however, the pairing of poetry and photography raises questions that are not easily dealt with in traditional terms. I want to focus on these issues by way of a close look at a single poem, Scottish poet Douglas Dunn's remarkable dramatic monologue, "St. Kilda's Parliament: 1879–1979." But first, I want briefly to provide the poem and photography itself some historical context.

Photographer Paul Strand claimed in a 1917 essay that photography "is the first and only important contribution thus far, of science to the arts" (219). A hyperbolic assertion, perhaps, but it points in a useful direction. For science, in its oldest meaning, is simply knowledge; and the modern era is characterized by countless developments in science and technology which, in supplying new ways of viewing the world, have thus influenced the arts directly or indirectly. Though not always mentioned with science and technology, the invention of photography has arguably had as much influence on our ways of knowing the world as any other: it has led to developments as varied as cinema, television, electron microscopy, surveillance cameras, and modern techniques of propaganda, advertising, and book printing and illustration.

Indeed, some writers have gone further than Paul Strand, declaring that photography has effected an alteration in human consciousness comparable to the theories of Darwin and Freud. As just one instance of such large claims, consider Walter Benjamin's famous essay of 1936, "The Work of Art in the Age of Mechanical Reproduction," in which he specifically details the way that photography, like Freud's theories, fundamentally modified the way we perceive our reality; and in which he also firmly places photography at the center of the political upheavals in modern life predicted by Marx. Whether such radical claims for photography may hold up remains an open question and falls outside the scope of this essay. But, as I will argue later on, photography has important links to at least one crucial development of modern thought, quantum physics.

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Since photography made it possible, as never before, for nearly everyone to record the features of loved ones, places visited, and public or private events, it has become a universal metaphor for remembering itself. It is this idea and its ramifications that I want to examine more closely. For if the ways in which photography has altered our views of reality are not yet fully charted, we may begin to understand them, at least, by looking closely at a single theme.

Photography's importance to the poetry of memory is obvious. What is less obvious, at least to the general public, is the possibility that in crucial ways photography has made it difficult to trust what we do recall. We all want to believe that the camera never lies, but, as we all probably sense instinctively, it does lie, and with a maddening, pervasive persistence. Not only does the camera portray reality as what it is not—a series of static, two-dimensional slices of time—but even more critically, the photograph cannot, by definition, capture what we tend to value most: the imaginative or interpretive meaning of a scene, its full context. John Berger is correct in pointing out that "unlike memory, photographs do not in themselves preserve meaning. They offer appearances—with all the credibility and gravity we normally lend to appearances—prised away from their meaning. Meaning is the result of understanding functions" (51).

Meaning can in fact be fraudulently imposed on a scene. This happens not just when there is propagandistic intent, but whenever a photograph is taken, because any photographer must frame the shot, decide on angles and exposures, and ultimately select the "best" picture for display. Similarly, as many photographic historians and critics have demonstrated, the visual information provided in photographs is sometimes inherently ambiguous; we need the captions in order to understand numerous photos. Janet Malcolm writes,

> One of the chief paradoxes of photography is that though it seems to be uniquely empowered to function as a medium of realism, it does so only rarely and under special circumstances, often behaving as if reality were something to be avoided at all costs. If "the camera can't lie," neither is it inclined to tell the truth, since it can reflect only the usually ambiguous, and sometimes outright deceitful, surface of reality. (77)

The photograph's ability to distort reality is, or ought to be, a truism. Yet photography does indeed capture something; as Susan Sontag notes, we assume that each photo, even if visually enigmatic, nonetheless is "a piece of the world" (93). As such, it still possesses an uncanny persuasive power, even when we know better than to trust it fully. Here is what is perhaps photography's richest paradox, between what Roland Barthes in his book *Camera Lucida* calls each photograph's "certificate of presence" (87) and its inevitable warpings of reality.

With these tensions and paradoxes in mind, I want now to look in detail at Douglas Dunn's poem, which appeared in 1981 as the title poem of his book *St. Kilda's Parliament*. In it he conducts a focused meditation, with far-reaching implications, on a single photograph. This image may have been invented by the poet, or it might be a fictive composite of many similar photographs. It is nevertheless treated as real in the poem's fiction. (Worth keeping in mind here is the likelihood that without the rich record of historical documentary photographs, Dunn, born in 1942, could not have written this poem.)

Since it is fairly long and not well known, I give the poem here in its entirety:

St. Kilda's Parliament: 1879–1979

The photographer revisits his picture

On either side of a rock-paved lane,
Two files of men are standing barefooted,
Bearded, waistcoated, each with a tam-o'-shanter
On his head, and most with a set half-smile
That comes from their companionship with rock,
With soft mists, with rain, with roaring gales,
And from a diet of solan goose and eggs,
A diet of dulse and sloke and sea-tangle,
And ignorance of what a pig, a bee, a rat,
Or rabbit look like, although they remember
The three apples brought here by a traveller
Five years ago, and have discussed them since.
And there are several dogs doing nothing
Who seem contemptuous of my camera,
And a woman who might not believe it
If she were told of the populous mainland.
A man sits on a bank by the door of his house,
Staring out to sea and at a small craft
Bobbing there, the little boat that brought me here,
Whose carpentry was slowly shaped by waves,
By a history of these northern waters.
Wise men or simpletons—it is hard to tell—
But in that way they almost look alike
You also see how each is individual,
Proud of his shyness and of his small life
On this outcast of the Hebrides
With his eyes full of weather and seabirds,
Fish, and whatever morsel he grows here.
Clear, too, is manhood, and how each man looks
Secure in the love of a woman who
Also knows the wisdom of the sun rising,
Of weather in the eyes like landmarks.
Fifty years before depopulation—
Before the boats came at their own request
To ease them from their dying babies—
It was easy, even then, to imagine
St. Kilda return to its naked self,
Its archaeology of hazelraw
And footprints stratified beneath the lichen.
See, how simple it all is, these toes
Playfullly clutching the edge of a boulder.
It is a remote democracy, where men,
In manacles of place, outstare a sea
That rattles back its manacles of salt,
The moody jailer of the wild Atlantic.
Traveller, tourist with your mind set on
Romantic Staffas and materials for
Winter conversations, if you should go there,
Landing at sunrise on its difficult shores,
On St. Kilda you will surely hear Gaelic
Spoken softly like a poetry of ghosts
By those who never were contorted by
Hierarchies of cuisine and literacy.
You need only look at the faces of these men
Standing there like everybody's ancestors,
This flick of time I shuttered on a face.
Look at their sly, assuring mockery.
They are aware of what we are up to
With our internal explorations, our
Designs of affluence and education.
They know us so well, and are not jealous,
Whose be-all and end-all was an eternal
Casual husbandry upon a toehold
Of Europe, which, when failing, was not their fault.
You can see how they have already prophesied
A day when survivors look across the stern
Of a departing vessel for the last time
At their gannet-shrouded cliffs, and the farewells
Of the St. Kilda mouse and St. Kilda wren
As they fall into the texts of specialists,
Ornithological visitors at the prow
Of a sullenly managed boat from the future.
They pose for ever outside their parliament,
Looking at me, as if they have grown from
Affection scattered across my own eyes.
And it is because of this that I, who took
This photograph in a year of many events—
The Zulu massacres, Tchaikovsky's opera—
Return to tell you this, and that after
My many photographs of distressed cities,
My portraits of successive elegants,
Of the emaciated dead, the lost empires,
Exploded fleets, and of the writhing flesh
Of dead civilians and commercial copulations,
That after so much of that larger franchise
It is to this island that I return.
Here I whittle time, like a dry stick,
From sunrise to sunset, among the groans
And sighings of a tongue I cannot speak,
Outside a parliament, looking at them,
As they, too, must always look at me
Looking through my apparatus at them
Looking. Benevolent, or malign? But who,
At this late stage, could tell, or think it worth it?
For I was there, and am, and I forget. (13–15)

Dunn's beautifully comprehensive poem manages to touch on most of the issues I have mentioned while focusing on the idea of using photography as an aid to memory. Precisely this problem has interested many poets: when memory and photography are at odds, as they must often be, which shall we trust? Dunn's subtitle, "the photographer revisits his picture," reminds us from the start of the difficulty in evaluating the past through both memory and photographic record. Presumably a visit will never be the same as a revisiting. In this case he puts the closely allied questions of memory's reliability and photography's truthfulness at the heart of things in several related ways. First, the photographed scene took place in a village that no longer exists: as the poem relates, the island of St. Kilda (actually a group of four small islands), located at the outermost of the Outer Hebrides, was depopulated fifty years after the photo was taken. Victorian Britons had been charmed to discover an example of a relatively primitive, "untainted" culture so close to home. The islanders had lived for centuries in comfortable isolation from technological developments on the mainland. Naturally, with the influx of tourists to their island, their way of life began to be disrupted with epidemic diseases as well as the breakdown of their traditional economy. In 1879, the year of the photograph, this process would have been well underway, though the end may not yet have been in sight. To twentieth-century ears, of course, that end has a sadly familiar ring: by 1930, the few who had not already emigrated had to be evacuated by the British government from a home that was no longer hospitable. The island is now a nature preserve and, with restoration efforts, is once again a destination for tourists (Tindall 169–71).

Whether or not Dunn is referring to an actual photograph, he is describing a common social use of photography. As James Guimond notes, from the inception of photography, "whenever people believe[d] that something [was] going to be destroyed, they rush[ed] to photograph it" (788). Photographers have always been "obsessed with the desire to capture what are called 'vanishing ways of life.' " Guimond continues, "photographers . . . have shared the . . . determination to record the images of aboriginal cultures which were on the brink of disappearing or being assimilated" (788). The nostalgic and sentimental impulse that, in America, produced stories, art, and photographic documentation of our "vanishing frontier," sent British Victorian photographers across the world in search of quaint, primitive, and exotic cultures. Finding such a people so close to home was especially exhilarating. The inescapable irony here, and one of which Dunn's narrator seems keenly aware, is that the curiosity for information about such endangered cultures helped contribute to their extinction.

Thus, the photographer in 1979 views a reality that is permanently ended. In addition, the photographer, unless he is well over a century old, must be speaking to us from the grave and so is himself doubly removed from the described scene. Therefore, he may also be intended as a sort of historical Everyman, looking back on the first century and a half of photography's existence. In any event, he makes it plain in his monologue that he feels at home neither in St. Kilda, "among the groans / and sighings of a tongue [he] cannot speak," nor in the "larger franchise" of modern life. I will have more to say about this uneasiness shortly.

Furthermore, we readers are distanced from the scene by its very unfamiliarity. As Dunn notes, these remote islanders photographed in 1879 live without knowledge of

> . . . what a pig, a bee, a rat,
> Or rabbit look like, although they remember
> The three apples brought here by a traveller
> Five years ago, and have discussed them since.

Such details clearly are what attracted tourists in the first place. These islanders were inevitably seen in patronizing terms by the inhabitants of industrialized Britain, praised and condescended to simultaneously, as representatives of the persistent myth of pastoral simplicity and innocence.

Obviously the barriers to comprehension here are formidable and many-layered. These islanders are inescapably *other* (different, strange) in habit, outlook, experience, and, of course, in time. The melancholy of such separation (even from someone, like the photographer, who has been there) is frequent in poems about photographs. Here, Dunn's narrator sees such separation, understandably, as being slightly threatening to him. Most of the men in the photo, he notes, display "a set half-smile / That comes from their companionship with rock, / With soft mists, with rain, with roaring gales . . . ." Even dogs "seem contemptuous of [his] camera," he feels, commenting of the islanders generally:

Wise men or simpletons—it is hard to tell—
But in that way they almost look alike
You also see how each is individual,
Proud of his shyness and of his small life
On this outcast of the Hebrides . . . .

This photographer is intelligent enough to know that however "alike" such people may look to the outsider's eye and the camera's lens, they maintain an ineffable individuality, one that he can only express, perhaps, by oxymoronic phrases like "proud of his shyness." This recognition shows up in many small details throughout the poem, in the poet's fussy or self-deprecating tone, in his cautious qualifiers, but most of all in his savoring of the visible details of the scene, tacitly recognizing that such appearances are the lion's share of what he really knows. In a sense, he can be sure only of what is outwardly apparent, such as the "toes / Playfully clutching the edge of a boulder."

We see more than a trace of envy, too, in the speaker's noting that each St. Kilda man looks "secure in the love of a woman who / Also knows the wisdom of the sun rising, / Of weather in the eyes like landmarks." These dead men and women, in other words, are secure in more than one sense: safe in each other's love, they are also secured against doubt by their customs and remoteness, and, finally, protected utterly from intrusion by their eternal dwelling in that vanished year. Here we are not far in spirit, of course, from the happy lovers on Keats's Grecian Urn, who, imprisoned in their artistic image, are thus preserved from the depredations of time and remain eternally young and lovely. As much as he leans on such romantic notions, however, Dunn never lets us forget that these St. Kildans were actual people in a real place.

The poem grows more explicit about the photographer's melancholy envy as it continues, granting these doubly exiled islanders an ironic triumph over both the reader and the photographer himself. In turning to address the modern tourist, the "Traveller," the narrator speaks across the double gulfs of time and poetic fiction, and explicitly implicates the contemporary reader in his themes:

. . . if you should go there,
Landing at sunrise on its difficult shores,
On St. Kilda you will surely hear Gaelic
Spoken softly like a poetry of ghosts
By those who never were contorted by
Hierarchies of cuisine and literacy.
You need only look at the faces of these men
Standing there like everybody's ancestors,
This flick of time I shuttered on a face.
Look at their sly, assuring mockery.
They are aware of what we are up to
With our internal explorations, our
Designs of affluence and education.
They know us so well, and are not jealous,
Whose be-all and end-all was an eternal
Casual husbandry upon a toehold
Of Europe, which, when failing, was not their
fault.

The sly mockery here is, of course, not so much read in the photo as read into it by the speaker, who believes that in many ways the more technologically advanced society which absorbed these people is inferior to their culture. No doubt he achieved this perception only as time passed. He may now regret his part, as a nineteenth-century tourist, in the corruption of the St. Kildans' traditional ways, even though as a photographer he is also party to its preservation in images. The St.

Kildans had, or so he now believes, no need for ''internal explorations'' (such as this poem, for instance), and were not warped by the presumably spurious ''hierarchies'' of civilized life, including ''literacy'' itself as well as ''designs of affluence and education.''

Up to this point Dunn's view of these islanders might seem sentimental, as if he saw them as somehow noble in their simple-minded farming of their ''toehold'' of an island. It is a familiar symbolic structure: ever since Virgil, poets have been lauding an Arcadian ideal, the rural life far from the corruptions of city and court. Yet if the language spoken by the St. Kildans, ''a poetry of ghosts,'' is the idiom of lost innocence, it is of a special kind. There is indeed an implicit judgment in their ''casual husbandry,'' an indictment of the mainland culture and its simplistic belief in progress. These islanders, after all, have survived since prehistoric times with an unchanging, self-sufficient economy, however primitive it might appear to outside eyes. However, the narrator is careful to declare that though the islanders may ''know us so well,'' that is, well enough to mock our obsessive trust in progress, still they ''are not jealous'' and evidently do not regret the imminent passing away of their own way of life. The islanders are not seen as simple pastoral types; they embrace modern life pragmatically or fatalistically enough, for their own unstated reasons.

The poem's photographer imagines that these people, fifty years in advance, have ''already prophesied'' their departure from St. Kilda, and still ''pose for ever outside their parliament, / Looking at me, as if they have grown from / Affection scattered across my own eyes.'' Although they were indeed real enough, their representation in the photograph derives precisely from the ''affection scattered'' across the photographer's eyes because the photographer has arranged the moment, posed them, and, most of all, preserved his photo for a century. Why did he do so? Why is he compelled (even from the grave) to revisit his own photograph? No doubt he needs to verify, with the photograph's aid, his feelings for these people and their vanished way of life. All ways of life are vanishing, from such a perspective, and the photographer is one whose profession involves an attempt to halt such flux. This effort is doomed, of course, and the photographer must know it as well as anyone does. He sees these islanders as not being jealous of him, we may presume, precisely because he is jealous of them.

The poignancy of such a moment—looking back at the photographed past, knowing absolutely its eventual dissolution and yet remembering, with the photo's aid, its vivid presence—is central to this poem and to others like it. In fact, as Roland Barthes has written, this paradox lies at the heart of historical photography's ability to move us. Commenting on an 1865 photo of a soon-to-be-executed criminal, Barthes notes:

> . . . *he is going to die*. I read at the same time: *This will be* and *this has been*; I observe with horror an anterior future of which death is the stake. . . . I shudder . . . *over a catastrophe which has already occurred*. Whether or not the subject is already dead, every photograph is this catastrophe. (96)

Similarly in Dunn's poem: ''looking at them,'' the photographer notes that ''they, too, must always look at me / Looking through my apparatus at them / Looking.'' Richard Powers, in *Three Farmers On Their Way To A Dance,* his complex historical novel revolving about a similar re-viewing of an old photograph, has suggestive things to say about such self-conscious moments:

> We scour *over* a photo, asking not ''What world is preserved here?'' but ''How do I differ from the fellow who preserved this, the fellows here preserved?'' Understanding another is indistinguishable from revising our own self-image. The two processes swallow one another. Photos interest us mostly because they look back. (332)

This unsettling feeling of being watched, even judged, that often comes to us while looking at old photographs, derives from the ''catastrophe'' Barthes describes, that shudder of recognition coexisting with the inevitable feeling of separation. It is normal to feel pity for the inhabitants of the past in old photographs because we presumably know more than they do; we may even know the details of their own future catastrophes. Yet, as Barthes knew and Dunn implies, what really animates our pity is the sense that these disappeared people also knew much that we never will. Likewise, the one invisible but suggestive presence in any old photograph, of course, is the photographer himself, who is just as much a disappeared person as the nominal subjects. Looking at a photograph we have taken spurs us to ask questions of ourselves the answers to which are largely lost.

Dunn's narrator concludes by asking, of the St. Kildans' looking through time at him, "Benevolent, or malign?" And he answers himself unsparingly: "But who, / At this late stage, could tell, or think it worth it? / For I was there, and am, and I forget." What does it all matter, then, if forgetting is inevitable, as it surely is?

The answer, to the extent that a paradoxical compromise can be one, must lie in the interplay of viewer and viewed. For the poem recognizes that there is really no such thing as disinterested observation. Having been to St. Kilda before its culture vanished, having been indulged by the islanders, the photographer is forever marked by the exchange. He feels impelled by "affection" to return not just to St. Kilda, but to "a year of many events— / The Zulu massacres, Tchaikovsky's opera . . . "—in other words, a year like any other, equally rich with human suffering and high achievement. His return both reflects and implicitly rejects "that larger franchise" of worldly pain, loss, dissolution, and tawdry display that this photographer confesses he spent many subsequent years recording, and from which these St. Kildans are forever protected:

. . . photographs of distressed cities,
My portraits of successive elegants,
Of the emaciated dead, the lost empires,
Exploded fleets, and of the writhing flesh
Of dead civilians and commercial copulations . . . .

Listed thus, these familiar elements of the modern age, so often the impetus for sensational photographs, seem flat and pathetic. Dead and gone, the people of St. Kilda cannot writhe or suffer exploitation. The photographer, in returning to tell them this, is obviously telling himself and us, and seeking (without real hope) the impossible stasis of a prelapsarian world. He finds that world not in memory, precisely, but in the shaping of memory represented by photography, which both preserves and distances the past and its inhabitants. His solace depends upon convincing himself not just that St. Kilda did indeed exist as he remembers it, but also that its natives were in fact *knowing* in a way forever denied to him. He senses their knowledge as a tight-lipped judgment of him, which he can feel but never fully understand. And thus, paradoxically, the photographer and his subjects are united while being forever separated.

This paradox, lying at the heart of the photographic act, is relevant to modern notions of the ambiguity and relativity of all knowledge. Einstein's central idea, like Freud's, has spread beyond its original context, becoming part of the intellectual inheritance of modernity. As Jacob Bronowski summarized it, "relativity is the understanding of the world not as events but as relations" (38), a remark that could fairly stand as a description of one of Dunn's themes here. The photographer revisiting his picture is not revisiting a thing or a place, but is involved in preceiving the relation between his various selves over time. Similarly, Werner Heisenberg's Principle of Uncertainty has infiltrated areas beyond quantum physics; many modern poets have been impressed by the fact that nothing can be measured without being in some way altered. If such a notion seems little more than common sense today, it is a mark of how deeply we have been influenced by such scientific ideas.

Photography, then, is like a scientific experiment: in recording reality, it also invariably changes it, however subtly. The subjects of any photograph always look back.

So if the photographer is to the people of St. Kilda like a "[visitor] at the prow / Of a sullenly managed boat from the future," they are to him the never escapable fact of his own and the world's past. The interplay of viewer and viewed is of the essence. Again, Richard Powers provides in his novel an eloquent gloss on this aspect of the poem:

> To look at a thing is already to change it. Conversely, acting must begin with the most reverent looking. The sitter's eyes look beyond the photographer's shoulders, beyond the frame, and change, forever, any future looker who catches that gaze. The viewer, the new subject of that gaze, begins the long obligations of rewriting biography to conform to the inverted lens. Every jump cut or soft focus becomes a call to edit. Every cropping, pan, downstopping receives ratification, becomes one's own. (334–5)

Thus have novelists and poets internalized, even if in oversimplified form, both relativity theory and Heisenberg's Principle of Uncertainty.

Photography, the art that is both of time and beyond it, is uniquely able to render such tensions. It is of time in that each photograph records a particular, actual instant; it is timeless in the same way any work of art is. As Dunn's speaker says earlier in the poem, "Here I whittle time, like a dry stick, / From sunrise to sunset, among the groans / And sighings of a tongue I cannot speak . . . ." Any photographer does this, of course, marking out the implications of the still scene which we know is never really stilled. So, as Dunn's speaker reminds us, a photo is not a record of time itself, or even of time's passing, but simply of discrete instants, paralyzed and solitary, like notches on a stick. Eventually, following the metaphor's implications, we must suppose that the stick will be whittled away; of course, there is one inevitable end to all memory, the grave.

Even before death, though, our efforts to remember and preserve the past are compromised. Indeed, the whole poem, in its anxious dependence on and swerving away from the consolations of Keats's "Ode on a Grecian Urn," suggests reflection on the limits of its own descriptive power. How well, after all, does Dunn's narrator succeed in rendering for us the material world of St. Kilda? His description at first seems tangible enough, studded with details of barefooted peasants, boats bobbing in the swells, dogs lounging about, and all the "manacles of place." And he is shrewd enough to lace his description with appealingly localized diction: "a diet of dulse and sloke and sea tangle," and an "archaeology of hazelraw"—precisely the kind of exoticism that draws in an armchair traveller.

A closer look at the poem, however, soon reveals that it is not very descriptive at all. The details noted above occur in its first half only and do not really add up to a very full picture. We have only to think of the pages that Conrad or D.H. Lawrence might have devoted to the photographed scene to realize how spotty and selective Dunn's description is. Furthermore, as the second half of the poem gives itself over entirely to reflection rather than description, Dunn continues to refer rather unconvincingly to what "you can see" in the photograph. Readers are informed, as I have noted, that they can see how the St. Kildans "have already prophesied" their departure; and that they are "aware of what we are up to" in our very different society. It is no mere literalism to point out that these are exactly the sorts of things that the readers cannot see; they are interpretive remarks not backed up by any tangible evidence from the scene. In fact, such judgments obviously cannot exist in any mute image.

Given the poem's frequent emphasis on what cannot be known (all part of the "poetry of ghosts"), it seems reasonable to suggest that Dunn's deepest concern here is to devise a language that is adequate not to the people of St. Kilda but to his own sighing, observing, and scattering of affection. To paraphrase Heisenberg, Dunn is not simply describing a memory but self-consciously examining his process of remembering. The pathos of this poem and similar ones is that it inexorably becomes aware of its own inadequacy at capturing outward events and their attendant meanings.

The more we study our time-bound world, then, the stranger and more remote it seems. And naturally, the more we rely on photos as aids to memory, the more our powers of memory are bound to deteriorate, and the more, in turn, we will seek out photography: a vicious circle. Just as the spread of printed books dealt a never-rescinded blow to the oral tradition of memorization and recital, the proliferation of photography into all areas of life has probably rendered it increasingly more difficult for us to recall and interpret what has happened. ''Not only is the photograph never, in essence, a memory,'' according to Roland Barthes, ''but it actually blocks memory, quickly becomes a counter-memory'' (91). To put it in less exaggerated terms, memory is a complex activity, rich with context and ripe with imagination, while a photograph's meanings are inevitably limited, cut off from context.

There is one final, related problem as well, which has occurred to nearly every commentator on the history of photography. As Dunn's fictive photographer is shrewd enough to notice, this age of the news photograph and documentary tends to conflate the values of all events, finding ''Zulu massacres'' precisely as interesting and photographically valuable as ''commercial copulations.'' As Sontag puts it: ''Images transfix. Images anesthetize'' (20). The result is another of the peculiar dualities of photography. Images anesthetize in that the very things we find touching in photographs, like the one of St. Kilda's Parliament, tend to lose, through over-exposure, their ability to move us. Images of almost everything that was once remote, sensational, or fascinating are so widely accessible that each one carries less and less of a kick. Yet at the same time, paradoxically, images transfix in that, with time, all photographs come to look like works of art, regardless of their subjects. Photography, for all its fabled truthfulness, can easily glorify abstract form, thus beautifying the ugly or the evil. In Max Kozloff's stern summary of the history of photography,

> the genres of information were all leveled, made interchangeable with each other and of equal value. International conferences, swimming meets, strikes, and doggie pranks came to have the same, unstressed, driveling importance. (23–4)

It is a sad enough circumstance: the glut of historical photographs causes them to lose their original significance, whether we look to them for truth or for beauty. In Dunn's poem, the casual juxtaposition of ''the emaciated dead'' and ''successive elegants,'' and of the ''writhing flesh / Of dead civilians and commercial copulations'' seem obvious instances of the leveling of value that Kozloff complains about. Less apparent, perhaps, is the way in which Dunn's photographer has inevitably, though unwittingly, aestheticized the grim reality of these St. Kildans' lives. Whatever hardships they have endured; whatever angers they feel; whatever pain or despair is to come—all tend to dissolve into the picturesque. Craggy, wind-marked faces are inescapably photogenic, and it is hard to avoid a sentimentalizing effect, however much the narrator wants to show contempt for tourists in search of ''materials for / Winter conversations.''

Ultimately, then, the ''sly, assuring mockery'' of the villagers in Dunn's poem is assuring us of one uncomfortable fact about our technological progress: that the more we have striven to grasp and record experience with our fine instruments of perception, the more impediments we have inadvertently placed between ourselves and reality—not just the reality of the past, but the present and the future as well. The ''tongue [the photographer] cannot speak'' is not just the Gaelic of the inhabitants of St. Kilda, but, more fundamentally, our failure to order and explain the mysteries of time and memory. It is an ancient theme after all, the chief novelty being our continuing naive belief in photography's accuracy.

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Wisconsin's Changing Dairy Industry and the Dairy Termination Program

John A. Cross

Abstract. *Wisconsin's leadership role in the United States dairy industry has increased over the past half century, although the number of dairy herds has declined by three-quarters. The U.S. Department of Agriculture's Dairy Termination Program eliminated over sixteen hundred of Wisconsin's dairy operations, with the leading milk producing areas losing proportionately the fewest operators. An additional twenty-four hundred dairy farms were lost during the two years since the first buyout herds were eliminated. Marginal areas within northern Wisconsin proportionately lost far more production than the state's leading milk producing areas. Most buyout participants remain in farming, relying upon hay and beef sales.*

The dairy industry of Wisconsin has been marked by a steady decline in the number of herds, an increase in herd size on the remaining farms, and a rising productivity per cow over the past several decades. In an effort to reduce milk surpluses Congress in late December 1985 enacted the Food Security Act of 1985 (Public Law 99-198). One provision of this legislation established the U.S. Department of Agriculture's Dairy Termination Program (DTP), whereby the dairy herds of participating farmers would be slaughtered or sold for export. This paper examines statistically the impact of the Dairy Termination Program, commonly called the whole-herd buyout program, on the changing spatial pattern of the dairy industry in Wisconsin, "America's Dairy Heartland." The impacts of the program upon the participating farmers and their future agricultural activities are also explored.

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Data Collection Methodology

Several strategies were utilized to collect data for this paper. Raw statistics were obtained from the Wisconsin State Agricultural Stabilization and Conservation Service Office concerning each accepted buyout bid and summary statistics reporting bids accepted, bids submitted, bid values, herd sizes, and 1985 milk marketing of accepted herds. A questionnaire was sent during June 1987 to each county-level office of the U.S. Department of Agriculture's Agricultural Stabilization and Conservation Service (ASCS) within Wisconsin. Because these officials had the responsibility of administering the DTP at the local level, it was anticipated that they could provide information concerning dairying trends within their counties, activities of DTP farmers, and characteristics of DTP farmers. Completed questionnaires were received for sixty-three of Wisconsin's seventy dairying counties (there are no commercial herds in Menominee and Vilas counties), representing a response rate of 90%. A four-page questionnaire was mailed in July 1987 to nearly four hundred farmers whose buyout bids were "potentially accepted." Completed survey forms were received from 305 farmers scattered throughout the state, representing a response rate of 80%. This survey queried farmers concerning their motivations for participating in the program, their past and present agricultural activities, their overall socio-economic characteristics, and their future intentions.

Changes in the Dairy Industry Since 1930

Wisconsin's national leadership in dairy production has increased over the past half century,[1] even though the nation's leading milk-producing county is found outside the state. In 1930 Wisconsin contained 8.9% of all U.S. milk cows. By 1985 this figure had risen to 17%. In 1930 Wisconsin's milk production was 11.2% of the nation's total, increasing to 17.5% by 1985 (Wisc. Agr. Stat. Ser. 1986). In 1930, three of the top five—and five of the top ten—milk-producing counties were found in Wisconsin. Although as recently as 1969 Wisconsin held two of the top five and five of the top ten positions (U.S. Bureau of the Census 1932 and 1972), by 1985 Wisconsin's only milk-producing county in the top ten was Marathon County, ranked eighth. Nevertheless, in 1985, ten of the top twenty milk-producing counties remained in Wisconsin (Wisc. Agr. Stat. Ser. 1986), the same share as in 1930. Nationally, the biggest shifts in milk production have been the declining prominence of New York counties (in 1930 St. Lawrence County, New York ranked number one nationally, with that state having six of the twenty largest producers) and the rising role of California (with eight of the top twenty counties and the nation's leading producer—San Bernandino County—by the mid-1980s). Wisconsin's milk production in 1985 was one and a half times that of California—the nation's second largest producer (Wisc. Agr. Stat. Ser. 1986). At that time 80% of Wisconsin's milk was used to manufacture dairy products, with Wisconsin producing 35.4% of the cheese and 23.7% of the butter produced in the United States. Thus in raw milk, cheese, butter, as well as condensed milk, Wisconsin's premier position is unchallenged.

At the beginning of 1986 Wisconsin's dairy herd included 1,876,000 dairy cows, the largest number since 1968 and less than 500,000 below the all-time high reached in the mid-1940s (Wisc. Agr. Stat. Ser. 1986). Although the number of Wisconsin dairy cows declined until 1978, it subsequently increased, rising 3.4% in the five years leading up to the buyout program. Largely because of greater milk production per cow (by genetic improvement of herds by use of artificial insemination, presently used to produce three-quarters of all Wisconsin calves), milk production in Wisconsin rose by 12.6% in the same half decade. By 1985 Wisconsin cows produced 25.1 billion pounds of fluid milk or an average of 13,383 pounds annually per cow (Wisc. Agr. Stat. Ser. 1986). Although the number of dairy cows within the state had only increased by 2% since 1930, the number of dairy farms[2] had plummeted 73.6% by the 1982 Census of Agriculture, a drop from 166,996 to 44,093 (U.S. Bureau of the Census 1932 and 1984). The number of commercial herds, represented by those undergoing the Brucellosis Ring test, dropped an additional 5.9% between March 1982 and March 1986, at which time Wisconsin had 40,950 dairy herds (Wisc. Stat. Rep. Ser. 1982; Wisc. Agr. Stat. Ser. 1986).

Considerable spatial variations were discerned in the impacts of these changes in Wisconsin's dairy industry. Declines in the number of dairy herds over the past half century (Fig. 1) as well as between 1981 and 1986 (Fig. 2) have been the greatest in the counties of northern Wisconsin, those counties encompassing and surrounding the Milwaukee metropolitan area, and several counties within the center of the state along the Wisconsin River. Indeed, two counties of northern Wisconsin no longer have any dairy herds. Overall the smallest declines in the number of herds have been in the south-

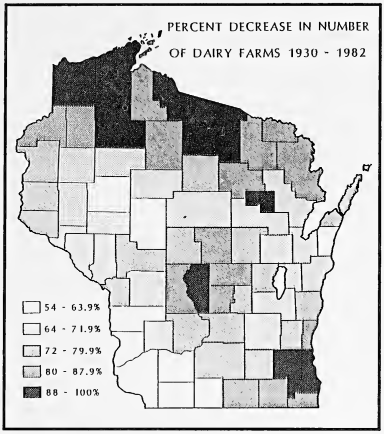
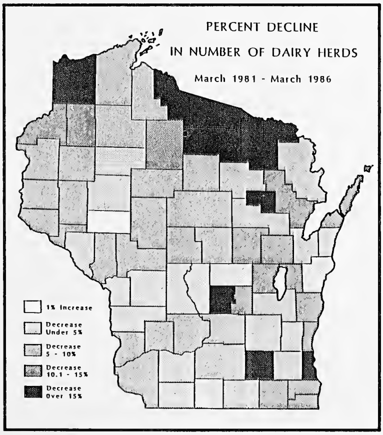


Figure 1

western counties. Although the number of dairy cows within the state as a whole rose slightly since 1930, six counties within northern Wisconsin recorded losses exceeding 50%, as did four counties in southeastern Wisconsin (Figs. 3 and 4). Conversely, large increases were noted in several counties of southwestern Wisconsin as well as in a band of counties extending across central Wisconsin from Kewaunee County on Lake Michigan, through Marathon County in the center of the state, to Buffalo and Pepin Counties along the Mississippi River. The most intensive dairying region of Wisconsin in the 1980s, if measured by the number of cows per square mile, is Calumet County, situated along the eastern shore of Lake Winnebago.

Participation in the Whole Herd Buyout Program

The U.S. Department of Agriculture's Dairy Termination Program thus came at a time when many changes were already reshaping Wisconsin's dairy industry (Table 1). Ninety-six hundred Wisconsin dairy farmers, representing 23.4% of Wisconsin's dairy herds, submitted bids to participate in this whole herd buyout program (Wisc. State ASCS 1986; Hill 1986; Wisconsin Agriculturalist 1986). Nearly seventeen hundred of these bids were provisionally accepted in March 1986. Thus, this buyout program eliminated 4.1% of Wisconsin's dairy herds between April 1986 and August 1987. The buyout herds totalled 62,633 cows. Although the dairy herds could either be sold for export or slaughter, 98% of the Wisconsin DTP dairy cows were terminated



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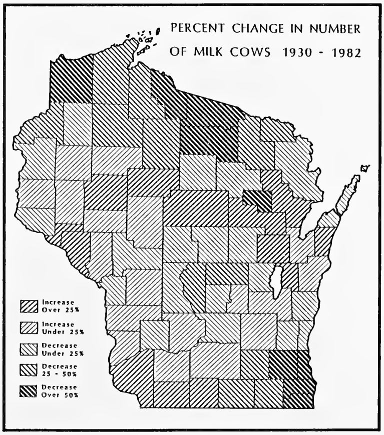

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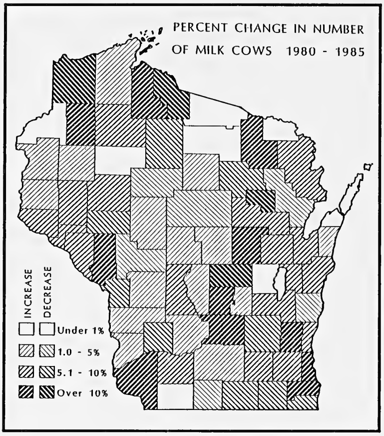


Figure 4

by slaughter. These terminated herds had accounted for 3.1% of the state's milk production in 1985 and contained 3.3% of Wisconsin's dairy cow population.

A smaller proportion of Wisconsin dairy farmers were accepted into the dairy termination program than within any other state except Nevada and Pennsylvania, even though Wisconsin led the nation in the number of total bids submitted—24.4% of all bids submitted nationally. Although nationally 35.4% of all bids submitted were accepted, Wisconsin's acceptance rate (17.4%) was by far the nation's lowest. Acceptance rates within all four states adjoining Wisconsin exceeded 40%, and Minnesota had the nation's largest number of herds accepted for termination—2,150 (Illinois State ASCS 1986; Iowa State ASCS 1986; Michigan State ASCS 1986;

Table 1. Recent decline in number of Wisconsin dairy herds and participation in USDA Dairy Termination Program by county.

County	*Number of Herds March 1986*	*Percent Decline in Herds 1981–86*	*Percent of Herds With Bids Submitted*	*Percent of Herds With Bids Accepted*	*Actual % Decline in Herds 1986–88*
Adams	100	3.8%	25.0%	10.0%	21.0%
Ashland	135	6.3%	31.1%	9.6%	15.6%
Barron	1,198	8.0%	22.4%	5.4%	11.4%
Bayfield	176	6.4%	22.2%	7.4%	22.7%
Brown	786	9.7%	31.0%	4.6%	12.1%
Buffalo	665	2.9%	24.1%	4.4%	12.0%
Burnett	196	10.1%	33.7%	10.2%	21.4%
Calumet	623	10.6%	24.1%	4.2%	9.3%
Chippewa	1,233	4.4%	20.6%	4.0%	7.6%
Clark	1,724	5.2%	19.5%	1.9%	7.1%
Columbia	526	7.6%	25.7%	3.8%	7.8%
Crawford	555	7.7%	28.8%	1.8%	7.9%
Dane	1,111	7.0%	25.8%	4.7%	10.0%
Dodge	1,248	7.6%	17.5%	3.3%	8.6%
Door	394	11.7%	27.7%	4.8%	11.7%
Douglas	55	17.9%	23.6%	7.3%	12.7%
Dunn	955	7.4%	26.5%	6.6%	11.7%
Eau Claire	585	(1.4%)	18.1%	5.5%	9.1%
Florence	27	20.6%	37.0%	11.1%	(3.7%)
Fond du Lac	1,052	6.2%	16.7%	3.1%	8.1%
Forest	41	18.0%	7.3%	2.4%	12.2%
Grant	1,302	5.6%	23.2%	3.1%	5.9%
Green	970	2.3%	19.3%	2.1%	6.3%
Green Lake	314	10.8%	24.2%	4.8%	7.0%
Iowa	830	2.5%	25.9%	2.8%	8.8%
Iron	17	19.0%	41.2%	23.5%	35.3%
Jackson	460	5.2%	23.5%	5.4%	8.9%
Jefferson	570	15.3%	18.2%	3.7%	11.0%

Table 1. Recent decline in number of Wisconsin dairy herds and participation in USDA Dairy Termination Program by county. (Continued)

County	Number of Herds March 1986	Percent Decline in Herds 1981–86	Percent of Herds With Bids Submitted	Percent of Herds With Bids Accepted	Actual % Decline in Herds 1986–88
Juneau	372	2.1%	25.0%	4.6%	9.7%
Kenosha	118	14.5%	27.1%	6.8%	8.5%
Kewaunee	656	9.0%	24.4%	2.3%	6.3%
LaCrosse	420	1.6%	19.3%	6.7%	11.0%
Lafayette	774	3.7%	30.1%	2.3%	3.6%
Langlade	281	9.6%	32.4%	5.7%	14.9%
Lincoln	280	9.4%	27.9%	4.3%	12.1%
Manitowoc	935	4.6%	19.8%	4.1%	10.2%
Marathon	1,971	7.9%	25.6%	1.9%	10.5%
Marinette	340	8.1%	27.1%	7.6%	12.9%
Marquette	158	16.4%	25.3%	5.1%	9.5%
Menominee	0	100.0%	No Commercial Herds in County		
Milwaukee	4	20.0%	0.0%	0.0%	(50.0%)
Monroe	1,006	.6%	20.5%	2.6%	4.0%
Oconto	683	11.4%	21.3%	6.1%	11.4%
Oneida	5	37.5%	40.0%	40.0%	20.0%
Outagamie	881	12.6%	30.2%	4.0%	10.6%
Ozaukee	190	12.4%	18.9%	8.4%	15.8%
Pepin	259	8.2%	26.7%	3.9%	9.7%
Pierce	603	5.0%	27.4%	5.8%	9.5%
Polk	833	8.9%	32.3%	8.3%	17.0%
Portage	495	6.8%	21.6%	4.8%	8.6%
Price	283	10.7%	26.1%	6.7%	19.8%
Racine	133	13.6%	23.3%	6.8%	13.5%
Richland	680	8.5%	23.5%	2.9%	5.3%
Rock	474	9.7%	23.2%	6.3%	11.4%
Rusk	549	1.6%	21.7%	2.9%	17.9%
St. Croix	772	5.2%	25.8%	4.8%	11.0%
Sauk	808	5.9%	24.7%	4.3%	10.4%
Sawyer	89	8.2%	33.7%	7.9%	10.1%
Shawano	1,156	7.0%	19.2%	2.2%	9.7%
Sheboygan	586	11.9%	23.7%	7.5%	11.4%
Taylor	811	7.2%	24.9%	2.2%	11.8%
Trempealeau	832	7.0%	26.9%	4.2%	9.4%
Vernon	1,291	4.9%	18.8%	1.7%	6.4%
Vilas	0		No Commercial Herds in County		
Walworth	337	11.8%	21.7%	9.8%	14.2%
Washburn	160	14.9%	24.4%	11.9%	24.2%
Washington	469	9.3%	19.0%	4.3%	11.3%
Waukesha	197	8.8%	22.8%	7.6%	14.7%
Waupaca	757	10.5%	22.2%	2.9%	7.7%
Waushara	297	3.6%	21.5%	8.1%	18.2%
Winnebago	491	12.9%	22.8%	4.1%	9.2%
Wood	666	5.4%	20.7%	1.1%	8.6%
WISCONSIN	40,950	7.1%	23.4%	4.1%	9.8%

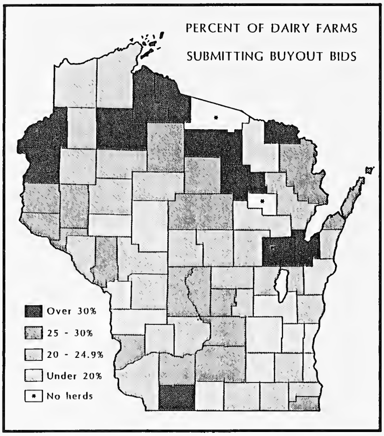
Data Sources:

Wisconsin State Agricultural Stabilization and Conservation Services Office. (1986). Madison: USDA. Unpublished statistics.
(number of bids accepted, and milk cows (excluding heifers and calves) accepted for termination)

Wisconsin Agricultural Statistics Service, 1986.
(number of herds tested for Brucellosis in March 1986 test period—used to calculate percentages.)

Wisconsin Agricultural Statistics Service, 1988.
(number of herds tested for Brucellosis in test period ending March 1988.)

Hill, 1986 and *Wisconsin Agriculturalist,* 1986.
(number of bids submitted and bids accepted.)



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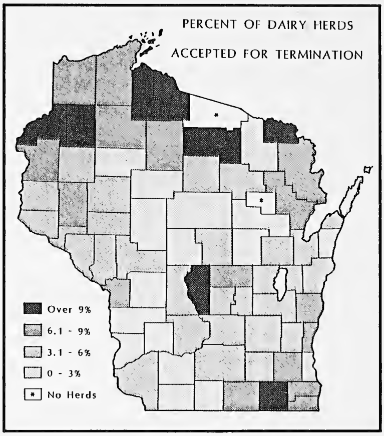

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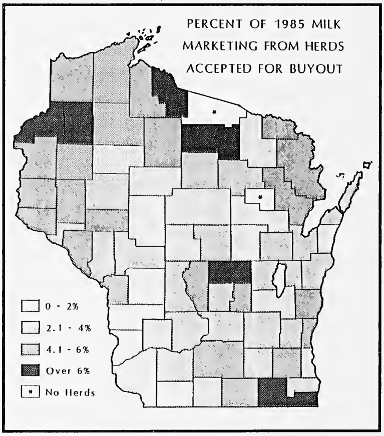


Figure 7

Minnesota State ASCS 1986; and Halladay 1986).

The proportion of dairy farmers within each Wisconsin county submitting buyout bids was the greatest within the counties of northern Wisconsin where 40% or more of the dairy farmers submitted bids in three counties (Fig. 5). With the exception of Milwaukee county (where no bids were received from that county's four dairy farmers) and Vilas and Menominee counties (where there are no commercial herds), Fond du Lac county dairymen were proportionately least likely to submit buyout bids, with only 16% submitting offers.

Although fewer than 2% of the dairy herds in the leading milk producing counties of central Wisconsin were accepted for termination, participation rates exceeded 10% in several counties of northern Wisconsin where dairying was already declining (Figs. 6 and 7). Indeed, the Dairy Termination Program reduced the number of herds in Iron and Oneida counties by 23.5 and 40.0%, respectively. Tables 2 and 3 and a comparison of Figures 1 through 4 with Figures 6 and 7 illustrate that participation in the buyout program was proportionately greatest in those counties already experiencing declines in dairying. Participation was proportionately the least within those counties experiencing the largest expansions in the number of dairy cows and having the greatest intensity of dairying (Table 4). A stepwise regression, with the proportion of dairy herds accepted for elimination as the dependent variable, found that the percent decline in number of dairy farms (1930–1982) and decline in commercial herds

Table 2. Long-term decline in number of dairy farms (1930–1982) and USDA Dairy Termination Program bid acceptances by county.

Percent Decline In Number of Dairy Farms:	*Percent of Farms with Buyout Bids Accepted*		
	Under 3 Percent	*3–6 Percent*	*Over 6 Percent*
Under 70 Percent	12	9	0
70–80 Percent	3	16	5
Over 80 Percent	2	4	19

Chi-Square = 42.19, Significance = .0000

Table 3. Recent decline in number of dairy herds (March 1981–March 1986) and USDA Dairy Termination Program bid acceptances by county.

Percent Decline In Number of Dairy Herds:	*Percent of Farms with Buyout Bids Accepted*		
	Under 3 Percent	*3–6 Percent*	*Over 6 Percent*
Under 6 Percent	8	10	3
6–10 Percent	6	12	8
Over 10 Percent	3	7	13

Chi-Square = 9.73, Significance = .0453

Table 4. Intensity of dairy farming (milk cows per square mile) and participation in USDA Dairy Termination Program by county.

Number of Milk Cows Per Square Mile:	*Percent of Farms with Buyout Bids Accepted*		
	Under 3 Percent	*3–6 Percent*	*Over 6 Percent*
Under 25	3	6	16
25–50	6	10	7
Over 50	8	13	1

Chi-Square = 18.63, Significance = .0009

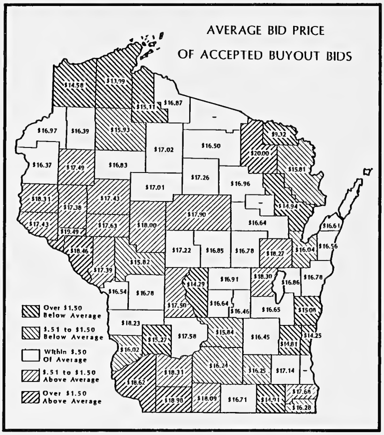
between March 1981 and March 1986 explained 56.3% of the variation of the dependent variable (Multiple R = 0.75).

The average value of the accepted buyout bids was generally highest within the counties of west-central and southwestern Wisconsin. On the other hand, the average bid in several counties of northern Wisconsin and within two counties near Milwaukee were over $2.00 less than the statewide average accepted bid of $16.85 per hundredweight (Fig. 8). Statistically, the greater the percentage of the county's dairy farmers who submitted accepted bids, the lower the average bid (Table 5).

The mean buyout herd size was generally highest within those counties having the most intensive dairy industry (Fig. 9). On the other hand, when the average number of head within the terminated herds is compared with the average herd size within the county, a different picture emerges. Throughout central Wisconsin the typical herd accepted for termination was smaller than the mean herd size within those counties, while within several counties of northern and southeastern Wisconsin the buyout herds closely approximated or exceeded the average herd size within the various counties.

Participant Characteristics

Participants in the buyout program represented a broad spectrum of Wisconsin dairy



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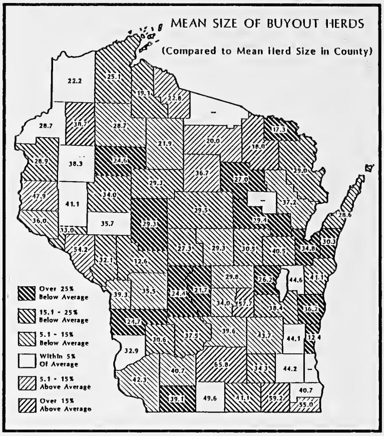

Figure 9

farmers. Several comments from county-level ASCS officials clearly make this point: "It was a typical cross-section of . . . farmers that submitted bids and were accepted. There was really no significant trend to any particular group of farmers"; "We [in a southwest Wisconsin county] did not notice any substantial differences—buyout producers ranged in age from 25 to 70—from 20 cows to 85 cows—from new farmer to experienced—it cut across all types"; and "those with accepted bids were either good operations or poor operations—as a group tended to be middle of the road. . . ." Although DTP participants were considered by ASCS officials (Table 6) as typical of the average Wisconsin dairy farmer with respect to their educational attainments, their farm acreage, and their herd grade, they differed, at least regionally, from continuing dairy operators in several key aspects, particularly age and experience.

The typical Wisconsin dairyman (all but 4% were male) participating within the U.S. Department of Agriculture's Dairy Termination Program was nearing retirement age and had operated his farm for at least twenty-five years. Indeed, 41.8% of the participants were at least sixty years of age, with only 13.4% under forty years old. These figures contrast sharply with the ages of Wisconsin dairy farm operators reported in the 1982 Census of Agriculture. For example, although the census indicated that individuals aged sixty-five years and older comprised 7.9% of the state's dairy farmers, this age group

Table 5. Average buyout bid price per county and participation in USDA Dairy Termination Program.

Average Price Of Accepted Buyout Bids:	*Percent of Farms with Buyout Bids Accepted*		
	Under 3 Percent	*3–6 Percent*	*Over 6 Percent*
Under $16.00	1	3	11
$16.00–$17.00	6	12	9
Over $17.00	9	14	4

Chi-Square = 14.88 , Significance = .0049

Table 6. Characteristics of typical DTP participants: Observations of county-level ASCS officials in Wisconsin.

"In comparison with the typical dairy farmer in your county, the . . .	*Below Average*	*Average*	*Above Average*
Farm Income of those dairy operators submitting buyout bids was generally:"	45.9%	46.2%	4.9%
Farm Acreage of those dairy operators submitting buyout bids was generally:"	21.3%	70.5%	8.2%
Dairy Herd Size of those dairy operators submitting buyout bids was generally:"	29.5%	62.3%	8.2%
Number of Years of Farm Experience of those dairy operators submitting buyout bids was generally:"	1.6%	52.5%	45.9%
Education of those dairy operators submitting buyout bids was generally:"	8.2%	86.9%	4.9%
Age of those dairy operators submitting buyout bids was generally:"	3.2%	55.6%	41.3%
Off-Farm Income of those dairy operators submitting buyout bids was generally:"	27.4%	62.9%	9.7%
Proportion of Farm Income Coming from Non-Dairy Agricultural Production (before termination) for those dairy operators submitting buyout bids was generally:"	27.4%	69.4%	3.2%
Proportion of those dairy operators submitting buyout bids which had *Grade A Herds* was generally:"	25.4%	54.0%	20.6%

comprised 20.1% of the Dairy Termination Program participants. Thirty-two percent of the state's dairy operators were at least fifty-five years old, but 56.9% of the DTP participants were this age. Conversely, the Census reported that 22.3% of Wisconsin's dairy farmers were under thirty-five (U.S. Bureau of the Census 1984), yet only 4.6% of the DTP participants were this young.

Eight percent of the Wisconsin DTP participants had entered dairying within the previous five years; however, the preponderance were leaving the dairy business after a lifetime of involvement. Only within the northernmost counties of Wisconsin, where dairying was already a marginal agricultural activity, and within the north-central portion of the state, including the major dairy counties of Marathon and Barron, did significant numbers of dairymen with less than fifteen years of experience enter the DTP. Indeed, within the northernmost counties 45.8% had less than fifteen years of experience, while 18.7% of those participants within the southern third of the state had that little longevity.

Economically, DTP participants were quite varied. Indeed, total 1985 milk marketing of these farmers ranged from a low of 225 hundredweight for one Price County farm to 118,808 hundredweight on a Dane County dairy, with their termination payments, correspondingly, ranging from $2,678 to $2,132,606. Nevertheless, average DTP herd size of thirty-seven cows plus twenty-seven heifers and calves was smaller than the average-sized Wisconsin herd. Although one ASCS official wrote that "surprisingly, many poorer producers didn't submit bids," the average buyout cow was 850 pounds under the state average in her milk production. Indeed, one DTP farmer wrote that he was participating because his cows were all old. Conversely, another ASCS respondent indicated that, at least within his central Wisconsin county, "for the most part they were more progressive farmers." For many participants, as discussed in the following section, their higher-than-average debt loads brought them into the program.

The overwhelming majority of DTP participants had herds of Holsteins (91.4%), with only 2% having Guernseys and 1% having Jerseys. The few remaining dairymen had herds comprised of several varieties. Thus, Holsteins are over-represented within the buyout program. Statewide, Holsteins account for 79% of Wisconsin's dairy herd, Jerseys for 13%, and Guernseys for 5% (Vogeler 1986). Fifty-five percent of the buyout herds were rated Grade A, similar to the 59.6% figure for all Wisconsin herds at the beginning of 1986 (Wisc. Agr. Stat. Ser. 1986).

Motivations for Entering Buyout Program

Buyout participants were asked both "What was the main reason you decided to submit your dairy buyout bid?" and to indicate the importance of several factors, including "desire to retire" and "farm debts" (Table 7). Responses to the first question indicated that although most participants had several motivations, age, poor health, and retirement were among the most frequently cited. Nineteen percent of the respondents explicitly mentioned that they submitted bids so they could retire, with an additional 23.6% indicating that their age or poor health were motivations. Although frequently related to age, the lack of help with the dairy operation was another frequently cited factor (by 9.8%), especially among those farmers whose children were no longer at home helping with the farm chores—a factor of critical importance to the typical labor-intensive family operation. These responses, together with the DTP participant's ranking of the importance of their "desire to retire" in the submission of their bids, indicates that 59.9% of the participants saw the program as a way to leave dairying for retirement, age, or health reasons. If those who cited a lack of help are included, this retirement figure rises to 63.3%. However, retirement from dairying should not imply that all these individuals have totally retired from farming. An additional 6.2% of the respondents indicated that a desire for more free time and less work—but not retirement—motivated their participation in the buyout program. Such motivations for DTP participation parallel the responses of farmers in Walworth, Rock, and Jefferson counties who were surveyed concerning their decisions to leave dairying before 1985. Indeed, Richler writes, "reasons included age of farmer, desire for a different life style, lack/cost of farm labor, and high capital investment and excessive debt vis a vis economic return" (Richler 1985).

Economic problems facing America's farmers, including over-production and low prices, have received considerable attention by journalists within the past few years. Indeed, the DTP was legislated in an effort to reduce milk surpluses. However, economic considerations were cited by only 39.5% of the survey respondents as a motivation for their participation. Nevertheless, 7.7% of the DTP participants entered the program to "get out of debt" and an additional 1.8% claimed their participation would enable them to avoid bankruptcy and a farm auction. The size of DTP payment that the farmers received was statistically related to their voiced concerns about their personal economic problems, with the dairymen who received the largest payments being most likely to express economic concerns.

The typical Wisconsin dairy buyout program participant had relied upon the sales of milk or dairy products to generate the pre-

Table 7. Motivations of DTP participants for terminating their herds.

"Please indicate the importance these factors in your decision to terminate your dairy herd:"	*Very Important*	*Somewhat Important*	*Slightly Important*	*Not Important*
Milk Price Levels	41.3%	25.8%	9.7%	23.2%
Size of Your Dairy Herd	7.4%	20.2%	17.2%	55.2%
Desire to Retire	31.2%	19.5%	11.1%	38.3%
Farm Debts	18.2%	9.4%	10.8%	61.6%
Distance from Dairy Plant	.3%	.7%	1.7%	97.3%
Other Job Opportunities	5.7%	8.1%	6.4%	79.8%

ponderance of his farm sales. Indeed, 50.1% indicated that milk sales accounted for at least four-fifths of their farm sales before they terminated dairy operations, while only 5.3% reported that milk and dairy products provided for less than two-fifths of their farm income. Fewer than one in ten reported off-farm income exceeding their income from farming before they sold their dairy herd, and over half the participants indicated that neither they nor their spouse had any off-farm employment.

Impacts Upon Wisconsin's Dairy Industry

Sixty-three thousand cows (plus 27,600 heifers and 18,500 calves) were accepted for slaughter or export under the buyout plan at a cost of $125.5 million (Wisc. State ASCS 1986). Nevertheless, during the eighteen months during which these DTP herds were eliminated, the number of milk cows in Wisconsin dropped by 93,000. By June 1988 Wisconsin's dairy herd had dropped to 1,760,000, the smallest number since 1920 (Wisc. Agr. Stat. Ser. 1988). However, because the average milk production per cow has been steadily rising (up by 9.1% in the past five years), total milk production is still higher than what it was at the beginning of the decade (Wisc. Agr. Stat. Ser. 1988). Viewed from this context, the Dairy Termination Program has only resulted in momentarily slowing the long-term trend of increased production that produced the milk surpluses the program sought to reduce.

The impact that the elimination of 4.1% of Wisconsin's dairy farmers through the buyout plan will have upon the long-term decline in the number of operators is more subject to speculation (see Table 1). By March 1988, the number of dairy operators in Wisconsin had fallen to 36,924 (Wisc. Agr. Stat. Ser. 1988). Thus in the two years since the first herd was slaughtered under the Dairy Termination Program, the number of Wisconsin dairy herds has dropped by 4,026—a whopping 9.8%. During the first year of the buyout program, when 71% of the 1,681 accepted herds were scheduled for termination, the number of Wisconsin dairy herds actually fell by 2,724, a drop of 6.7% (Wisc. Agr. Stat. Ser. 1987). Within the previous five years, between March 1981 and March 1986, the number of dairy farms within Wisconsin had decreased by only 7.1%.

Nearly 8,000 of the Wisconsin dairy farmers who submitted buyout bids had their bids rejected, being in excess of the $22.50 per hundredweight cut-off. Thus, had all the submitted bids been accepted, 22.9% of the state's dairy operations would have been eliminated—far more than the actual 4.1%. County-level ASCS officials estimated that one-quarter of these individuals would leave dairying by 1992, the year that participating farmers may begin to re-enter the dairy business. However, the loss of nearly twenty-four hundred Wisconsin dairy operators who were not DTP participants within the past two years indicates that these officials' estimates may be too conservative.

The total declines in the number of dairy herds between March 1986 and March 1988 (including the DTP herds) are indicated in Figure 10. Comparison of this map with those of previous declines and DTP participation indicates that the problems facing dairy operators in the northernmost portions of Wisconsin appear to be expanding farther south. For example, historically the highest rates of decline (in northern Wisconsin) were in those counties along Lake Superior and the Michigan border (plus Oneida county). The decline in this last two-year period has extended farther south to include Polk, Rusk, Langlade, and Marinette counties, which all had substantial numbers of herds. Polk county lost 17% of its herds. Rusk county lost 18%. Even the state's leading dairying county, Marathon, reported a decline exceeding the state average. Although Milwaukee county actually showed an increase (the county had only six dairy operations in early 1988), declines in the collar counties all greatly exceeded the state average. Of particular interest is the continued prosperity of dairying in the state's southwestern corner. This area experienced the smallest decline in number of dairy operators between 1930–1982, below average declines between 1981 and 1986, below average DTP participation, and decreases in the number of herds between 1986 and 1988 that were half of the state average. Grant and Vernon counties are now the state's third and fourth leading counties in number of herds.

Farming Activities in 1987

Most of the buyout farms remained in some type of agricultural production in 1987. Livestock production was still occurring on 73% of the operating DTP farms (Table 8). Beef production was most common, being reported by 95% of DTP operators raising livestock, many who indicated they were now concentrating their efforts upon "dairy beef" or "Holstein steers." Beef production was uniformly attractive to these former dairymen across the state. Hogs were being raised by one-fifth of those farms with livestock. Hog production, although reported by former dairymen throughout Wisconsin, was most attractive to farmers within the southwestern portion of the state. Nearly one-third of all DTP farms in production within southwestern Wisconsin were raising hogs in 1987. Although other farmers reported raising chickens, sheep, goats, horses, and donkeys, not one of these animals was found on as many as 5% of the DTP farms.

Statewide, 96% of those DTP participants whose farms were in production reported that crops were grown in 1987. Only in Wisconsin's northernmost counties did any sizeable number of these farmers report that crops were not being produced. The most commonly grown crops were hay (on 86.7% of all operating DTP farms), corn (on 78.4%), and oats (on 43.8%).

Hay (including alfalfa and clover) was uniformly popular as a crop among former dairy operators across Wisconsin, although the distribution of corn and oats was spatially less uniform. Corn was produced on at least 80% of all operating DTP farms except for the northernmost area, where only one-third of

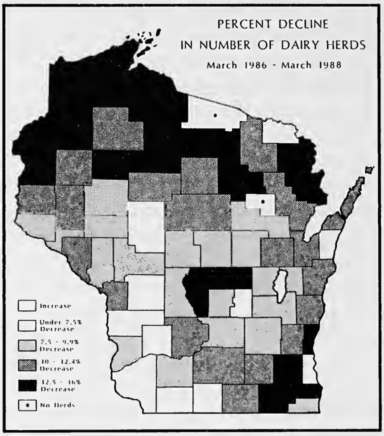

Figure 10

the farms were growing the crop. Oats, likewise, were under-represented in the northern counties, although they were least popular within southeastern Wisconsin.

Less commonly grown crops included soybeans (on 11.5% of all operating DTP farms), tobacco (on 4%), vegetables (4.9%—including sweet corn, peas, and snap beans), and barley (4%), plus several other crops—none of which were reported by more than 2% of the DTP participants. Although soybeans were grown by a few farms in all areas of the state, only within southwestern Wisconsin did as many as a third of the farmers cultivate this crop. Tobacco was only grown by DTP farms in the south-central and southwestern portions of Wisconsin. Vegetables were predominately grown by DTP participants in south-central Wisconsin.

Most DTP farmers reported production of several crops and livestock. Hay and beef, however, were expected to provide the greatest source of farm income (Table 9). Indeed, when asked "what single crop or livestock do you expect to provide the most income to your farm this year [1987]?" statewide 35.7% indicated hay and 33% reported beef. Hay was either the first or second most frequently cited income source in every region of Wisconsin, while beef was similarly reported in

Table 8. Agricultural activities of DTP farms remaining in production—1987.

	*Region of Wisconsin**							
Type of Production	*Far North (N = 45)*	*North Central (N = 36)*	*Central (N = 32)*	*East Central (N = 27)*	*South-West (N = 31)*	*South Central (N = 35)*	*South-East (N = 20)*	*Wisconsin Total (N = 226)*
Livestock	75.6%	69.4%	75.0%	70.4%	80.6%	68.6%	65.0%	72.9%
Beef	73.3%	66.7%	68.7%	70.4%	77.4%	65.7%	65.0%	69.9%
Hogs	8.9%	11.1%	12.5%	7.4%	29.0%	17.1%	15.0%	14.2%
Crops	84.4%	100.0%	100.0%	100.0%	93.5%	100.0%	95.0%	95.6%
Hay	80.0%	100.0%	84.4%	96.3%	93.5%	82.9%	65.0%	86.7%
Corn	33.3%	83.3%	100.0%	81.5%	90.3%	94.3%	85.0%	78.4%
Oats	31.1%	55.6%	15.6%	70.4%	51.6%	48.6%	40.0%	43.8%
Soybeans	4.4%	5.6%	15.6%	11.1%	6.5%	14.3%	35.0%	11.5%
Tobacco	0	0	0	0	12.9%	14.3%	0	4.0%
Vegetables	0	5.5%	6.2%	0	0	17.1%	5.0%	4.9%

*Regions, unless otherwise specified, correspond to Wisconsin Agricultural Statistics Service reporting districts. The Far North region includes the N.E. District and the northern counties of the N.W. and N.C. Districts. The North Central Region includes the southern counties of the N.W. and N.C. Districts, including Marathon and Barron counties. The South-West region includes both the S.W. and W.C. Districts.

Table 9. Chief agricultural products of DTP farms remaining in production—1987.

	*Percent of Farmers Reporting Item as Greatest Source of Farm Income by Region of Wisconsin**							
Crop or Livestock	*Far North*	*North Central*	*Central*	*East Central*	*South-West*	*South Central*	*South-East*	*Wisconsin Total*
Hay	50.0%	44.4%	29.6%	46.1%	20.0%	20.7%	33.3%	35.5%
Beef	35.0%	29.6%	37.0%	26.9%	46.7%	24.1%	27.8%	33.0%
Corn	0	14.8%	18.5%	14.8%	20.0%	27.6%	33.3%	16.8%
Other	15.0%	11.1%	14.8%	11.5%	13.3%	27.6%	5.6%	14.7%

*Regions same as defined in Table 8.

all areas except the south-central and southeastern parts of the state where corn was equal to hay in importance.

On-Farm and Off-Farm Employment in 1987

The summer of 1987 found the former dairy farmers looking towards other economic pursuits. One-third (32.7%) of the DTP participants reported that either they or their spouse had obtained off-farm employment since entering the program, while one-fifth had retired. Jobs that these farm operators reported having in mid-1987 ranged from providers of farm services to factory workers, from unskilled laborers to plumbers and electricians, and from sales to the professions. Although great employment diversity was reported, several of the most frequently reported off-farm jobs included driving trucks (7% of those not retired), driving school busses (2.6%), logging (2.6%), and sales (of all varieties, 6.1%). Nevertheless, of those who had not retired, farming was still considered by half of the DTP participants as their occupation in 1987.

Farming remains the primary occupation for most DTP participants. Although many commented about how much they missed their cows, the long hours without any vacation were not missed. Although 59.9% indicated that a motivation for leaving dairying was to retire, 96% of those who owned farmlands before they entered the DTP still owned their lands, even though 22.9% of these persons responded that they wished to sell their farms. Of those farmers who had not sold their farms, 22% rented their lands to other farmers, but only 5.5% of the farms had been totally taken out of production (with three-quarters of these located within the northern third of Wisconsin). Thus, 74% of the Wisconsin dairy farmers who entered the DTP still had at least part of their lands in production in 1987.

Statewide, 18.3% of the DTP participants entered at least part of their farmland into the Conservation Reserve Program, whereby lands vulnerable to soil erosion are removed from production. This program included one-third of the buyout farmers within the southwestern and south-central portions of Wisconsin. Undoubtedly, more farmers would have entered this program had their lands been eligible, as several farmers responded that their requests for inclusion into the program were rejected because their lands were too level.

A Return to Dairying?

The vast majority of buyout participants were satisfied with their decision to enter the program. In response to the question "Do you still think you made the correct decision by participating in the dairy herd buyout program?" 79.7% answered affirmatively, 7.3% responded negatively, while 13% were uncertain. The farmers who had the most productive cows were significantly more satisfied with their participation than those with below-average milk yields.

When surveyed after being in the buyout program for one year, fewer than one in ten of the DTP participants indicated that they planned to re-enter dairy operations after the required five-year moratorium elapses. A much smaller survey, conducted by the *Wisconsin Agriculturalist* shortly after the winning bids were announced, found that only one out of fewer than one hundred respondents hoped to return to dairying (Morrow 1986). In response to a direct inquiry on my survey, 7.3% indicated that they intended to return to dairying, 23.8% responded that they were uncertain, while 68.9% stated they had no intention. Such responses were not surprising considering the large proportion of the buyout participants who used the DTP as an avenue for retirement. Indeed, only 20.3% of Wisconsin farmers within the buyout program expected to still be dairying within five years if their herd had not been accepted for termination. An additional 26.3% replied that they were uncertain as to whether they would be operating by 1992. Even among those dairy operators under fifty years of age, 39.8% expected to have left dairying by 1992, and an additional 26.5% were uncertain as to whether they would still be in business. Thirteen percent of those buyout farmers who were not retiring expected to re-enter dairying, although 44.3% felt they had permanently left the business. Thus, only one of twenty Wisconsin buyout participants had any intention of returning to dairying.

The Dairy Termination Program, in conclusion, has sped up the consolidation of Wisconsin's dairy industry into fewer hands. However, this shrinkage would have occurred even without the program; most participants would have quit dairying anyway because of age or economic pressures. The ongoing process of farm consolidation statewide and retrenchment from the agricultural frontiers of northern Wisconsin and the central Wisconsin River Valley and from the expanding urban areas in southeastern Wisconsin has only been hastened. Participation rates were less than 2% in the leading milk producing counties of north-central Wisconsin, while rates exceeded 10% (to as high as 40%) within Wisconsin's northernmost counties where historically dairying was already in a precipitous decline.

Even without the cows, most DTP participants in Wisconsin remain involved in agricultural pursuits. Considering that a smaller proportion of DTP bids from Wisconsin farmers were accepted than within any other state and that Wisconsin's herd was proportionately reduced less than within any state except Nevada and Pennsylvania, Wisconsin remains the nation's dairyland. If anything, its role has been strengthened. Likewise, the same arguments may be made within Wisconsin. Marginal areas within the northernmost counties proportionately lost far more production than the state's leading milk producing areas. Considering the proportion of DTP participants who continue to produce hay (and that one-third still consider it their leading source of farm sales) and those who have concentrated upon cultivating feed grains, farmers remaining in dairying should find little—save low milk prices—to keep them from expanding their herd sizes. In the past, such overproduction has done little to diminish overall production; it has just driven the less productive producer out of business and concentrated production into fewer hands. In retrospect, it is doubtful whether the Dairy Termination Program will have any lasting effect upon overall milk production, but it may have accelerated the process of farm consolidation and the increased size of the remaining operations. The USDA Dairy Termination Program has merely advanced trends that have been redefining Wisconsin's dairy industry for over a half century, spatially restricting the dairy belt within the state.

Notes

[1]Comparable data on the number of Wisconsin farms reporting milk cows is unavailable for censuses before 1930.

[2]The 1930 and 1982 U.S. Census of Agriculture data on the number of farms reporting milk cows was utilized. The Wisconsin Agricultural Statistics Service reports precise data on the number of dairy herds that have had the Brucellosis Ring test, required for all commercial herds. The Wisconsin statistics may not precisely correspond to the U.S. Census data (which is also adjusted to compensate for nonresponse and sample errors). The 1982 Census was the most recent prior to the beginning of the DTP, while the Brucellosis Ring Test data for the period ending March 1986 immediately preceded the beginning of the buyout program.

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Survey of Timber Rattlesnake (*Crotalus horridus*) Distribution Along the Mississippi River In Western Wisconsin

Barney L. Oldfield and Daniel E. Keyler

Abstract. *A study of sites ranging from southern St. Croix County to northern La Crosse County along the Mississippi River Valley was made to determine the current geographical distribution of the timber rattlesnake* (Crotalus horridus) *in western Wisconsin. A total of forty-two surveys were made at sixteen different sites from April 11, 1988, through October 15, 1988. A total of twenty-five specimens were observed with the earliest observation being made on May 1 and the latest on September 11. Limited biological data were obtained on eighteen snakes. The most northern and southern specimens came from northwestern Pierce County and southern Trempealeau County, respectively. A single specimen found 16.9 km from the Mississippi River in Buffalo County represented the furthest inland observation. Of the forty-two survey trips,* C. horridus *were only observed on sixteen occasions. Large numbers of snakes were not found at any one site. Thus, the timber rattlesnake may not be as widely distributed or present in as large of numbers as have been reported historically. These preliminary data suggest the need for further investigation of* C. horridus *distribution and population in western Wisconsin and may even warrant the need for both habitat and species protection.*

Wisconsin and Minnesota are the most northwestern geographical range of the timber rattlesnake *(Crotalus horridus)*. Early reports of this species in Wisconsin date back to 1680 when L. Hennepin, on a voyage up the Mississippi River, observed "Serpens Sonnettes" or what is now known as the timber rattlesnake. Later in 1700, Le Seur reported that it was dangerous to enter caverns near Lake Pepin because of rattlesnakes (Schorger 1968). Historical references yield reports of ninety-nine specimens being found in a single day at a single site, confirming the existence of large populations in the past (Schorger 1968). It is the concentration of this species in a given area for denning and/or other reasons that has made the species vulnerable to predation by man. *Crotalus horridus* represents the largest species of rattlesnake occurring in the northern United States (Klauber 1982), and its notoriety rivals that of another wilderness species, the timber wolf *(Canus lupus)*. Prior to 1975, large numbers of timber rattlesnakes were taken in Wisconsin when the state's

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bounty system was still in force. Although historically the timber rattlesnake was afforded a much wider range, as literature and museum records attest to, more recent records on distribution (Cochran 1986) and population status for this species have been sparse. Therefore, the current study was undertaken to determine the present-day distribution of *C. horridus* along the Mississippi River valley in western Wisconsin.

Methods and Materials

Timber rattlesnake museum records and published literature were used initially to establish known historical distribution for the seven western Wisconsin counties under study (St. Croix, Pierce, Pepin, Buffalo, Dunn, Trempealeau, and La Crosse). USGS quadrangle (7.5 minute series) topographical maps were evaluated for potential timber rattlesnake survey sites. USGS Wisconsin county quadrangle maps were used to plot survey sites and results. Early in the study, prior to snake emergence in the spring, and on days of inclement weather, time was spent driving country roads to search for potential denning areas. Also, several landowners were interviewed concerning known local snake populations.

It became evident during the study that conducting site surveys to establish the presence of the timber rattlesnake could be a time-consuming activity. This made it necessary to concentrate efforts in the four central counties of the survey area.

Sites were surveyed on foot. Careful searches for rattlesnakes were conducted in accessible habitat. When a snake was found if possible, it was captured with a Furmont snake hook, and biological data were recorded. A Miller and Weber cloacal thermometer was used to measure body temperature. Sex of the snake was determined using Furmont snake sexing probes (Fuhrman Diversified, Inc., La Porte, Texas). Live measurements from snout to base of rattle and from snout to vent were taken with a conventional tape measure. The rattles were counted beginning with the button as 0 and all free segments thereafter numbered consecutively. The animal was placed in a cloth bag and weighed with a Sargent-Welch spring scale (Sargent-Welch, Skokie, Illinois) with either a 0–2000 gm range or a 0–200 gm range scale previously tared for bag weight. After release at the capture site, photographs were taken. A Taylor digital thermometer (Markson, Phoenix, Arizona) and a Miller and Weber surface thermometer (Miller and Weber, Inc., Queens, New York) were used to record air and substrate temperatures.

Several sites were repeatedly surveyed in an attempt to establish the presence of *C. horridus* at a particular site and to obtain population data from sites where snakes were known to occur. All snakes were handled for study in accordance with the 1987 *Guidelines for Use of Live Amphibians and Reptiles in Field Research.*

Results

Habitat. A total of sixteen different geographical sites were surveyed on forty-two different occasions. The sites had many similarities; all had areas of rock, bluff prairies, Oaks (*Quercus* spp.), and other mixed vegetation and were at elevations between 198 m and 350 m above sea level (Table 1).

Distribution and Numbers. The northernmost site at which a specimen of *C. horridus* was observed was PIE-6 (Clifton, Civil town, Pierce County) and the southernmost site of observation was TRE-1 (Trempealeau, Civil town, Trempealeau County). These were also the northern and southern extremes of sites surveyed (Table 1, Fig. 1). A single site approximately 16.9 km inland from the Mississippi River BUF-3 (Alma, Civil town, Buffalo County) yielded a single specimen. A total of twenty-five specimens of *C. horridus* were found during the course of the study. However, these were only observed at nine of the sixteen different sites surveyed. One female specimen was observed on three different occasions. The largest number of snakes found at a given site over the period

Table 1. Geographical Location and Habitat of Timber Rattlesnake Sites Surveyed in Western Wisconsin

Site	County	Civil Towns	Habitat
PIE 1*	Pierce	Isabelle	Limestone outcrop without loose boulders; intermittent bluff prairie, Oak, Cottonwood, Cedar, Bittersweet, elevation 274–320 m.
PIE 2		Isabelle	Large limestone bluff, some loose rock, many Cedars, Oak, Grape Vine, Bluff Prairie, elevation 274–320 m.
PIE 3*		Diamond Bluff	Scattered limestone boulders, heavy vine vegetation, intermittent Bluff Prairie, Oak, Birch, elevation 213–274 m.
PIE 4*		Trenton	Large limestone bluff, Sumac, Oak, Birch, intermittent Bluff Prairie, elevation 244–305 m.
PIE 5		Heartland	Limestone outcrop, heavy Oak, some grass areas, elevation 274–320 m.
PIE 6*		Clifton	Woodland of Oak, Elm, Maple below small limestone outcrops, river flood plain area, elevation 213–244 m.
PEP 1*	Pepin	Stockholm	Large limestone bluff in tiers, steep, intermittent bluff prairie with Cedar, Oak, elevation 229–305 m.
PEP 2		Stockholm	Sandstone formations, Cedar, Birch, bluff prairie, elevation 244–305 m.
PEP 3		Pepin	Large bluff prairie, some scattered limestone shelves, Sumac, Oak, elevation 305–335 m.
PEP 4		Stockholm	Limestone rocks, railroad ties, fallen trees, Oak, Elm, Maple, grape vine, elevation 198–213 m.
BUF 1*	Buffalo	Nelson	Large sandstone formations with loose slabs mixed with grass, Cedar, Hackberry, Oak, elevation 274–335 m.
BUF 2		Alma	Scattered limestone around old quarry, Birch, Grape vine, Cedar and Oak, elevation 274–335 m.
BUF 3*		Alma	Limestone boulders scattered, bluff prairie, Birch, Cedar, Oak, elevation 274–335 m.
BUF 4		Milton	River flood plane forest, grass, Oak, Maple, Birch, elevation 213–244 m.
BUF 5*		Milton	Community below limestone bluffs, elevation 213–244 m.
TRE 1*	Trempealeau	Trempealeau	Large limestone, sandstone rock, some loose rock, Cedar, Birch, Oak, elevation 305–350 m.

*Timber Rattlesnake confirmed at these sites

of the study was twelve, and the most snakes found at a single site at a given time was five (Table 2).

Chronology of Surveys and Climatology. The first spring survey was made on April 11, with the first specimens not being observed until May 1. In the fall, surveys were made until October 15, but the last specimen was seen on September 11 (Table 2). All surveys were made between 1100 and 2000 hours. The average air and substrate temperatures were 28.3°C and 30.1°C, respectively. Weather conditions varied considerably from sunny to cloudy, calm to windy, and hot (29.8°C) to cool (16.8°C) with specimens having been observed under all the different conditions (Table 2).

Biology. Of the twenty-five specimens of *C. horridus* observed, limited and incomplete biological data were obtained due to limited numbers of field personnel and equipment, snakes unable to be captured, and precarious circumstances on several occasions (Table 3). The mean body temperature for nine specimens was 29.6°C. Total body lengths ranged from 35.5 cm to 123.2 cm, and body masses ranged from 30 g to 1110 g. Two snakes had complete rattles of eight seg-

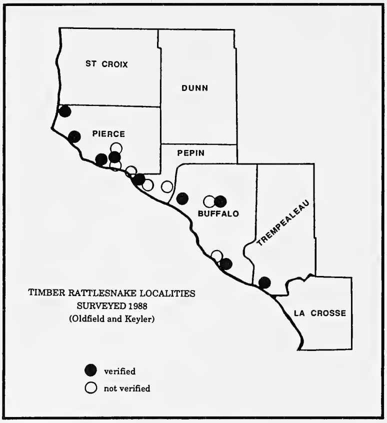

Figure 1

ments; these were the largest rattles observed. Of the nine specimens in which sex was determined, five were female and four were male and were from seven different sites. Two females were determined to be gravid by palpation. An interesting observation was noted on two specimens as they possessed post-ocular stripes and prominent mid-dorsal stripes. These markings were apparent on a female and a male from different sites.

Discussion

Timber rattlesnakes have been extirpated in many areas of Wisconsin; thus, they remain in the most rugged and nearly inaccessible micro-wilderness areas of the state. Because of this fact, their secretive nature, and their absence for six to seven months of the year due to hibernation, they are a difficult animal to study. Furthermore, legends and stories have contributed a variety of unfounded reasons for man's irrational fear of the animal.

The objectives of this field survey of *C. horridus* were to ascertain present-day distribution in seven counties for historical comparisons, to assess habitat requirements in western Wisconsin, and to make recommendations regarding conservation of the species. A substantial amount of information was gathered to fulfill these objectives considering the extent of the geographical area under study and constraints of time and budget. Although incomplete, some biological data were accumulated during the study.

Crotalus horridus is a species of the steeply dissected, forested hills along the Mississippi River and its tributaries in western Wisconsin. The snake reaches the extreme northwestern limit of its U.S. range here and in

Table 2. Chronology, Climatology, and Number of Timber Rattlesnakes by Study Site

Date	*Time*	*Site*	*Weather*	*Air Temp (0°C)*	*Substrate*	*No. Rattlesnakes*
May 1	1200–1300	PIE-1	clear, sunny, windy	24.3	30.0	2
May 13	1330–1430	PEP-1	clear, sunny, windy	28.3	18.3	2
May 18	1100–1230	PIE-1	overcast, breeze	23.4	30.0	3
May 18	1300–1400	PEP-1	clear, slight breeze	25.0		1
May 21	1330–1430	PIE-3	clear, calm, humid	29.6	38.0	1
May 21	1545–1710	PIE-1	high overcast, calm	27.4	32.0	5
May 23	1200–1330	PEP-1	clear, sunny, calm	26.8		1
May 23	1600–1800	PIE-4	clear, sunny calm	29.8	38.0	2
May 28	1200–1300	BUF-1	partly cloudy, rain	24.0	30.0	1
May 28	1930–2000	PIE-1	clear, almost dark	27.5	32.0	1
May 30	1115–1300	BUF-3	hazy, breeze	26.5	31.0	1
June 4	NA	BUF-5	NA	NA	NA	1 (dead)
July 30	1515–1600	PIE-6	clear, sunny, humid	28.8	32.0	1
Sept. 3	1700	TRE-1	cool, rain, calm	16.8	21.0	1
Sept. 11	1000–1145	PIE-1	clear, calm	28.1	30.2	1
Sept. 11	1210–1300	PEP-1	clear, breeze	28.0	28.4	1
Mean + SD				26.3 ± 3.3 n = 15	30.1 ± 5.5 n = 13	

NA = not applicable

Table 3. Various Biological Information for 18 Timber Rattlesnakes by Study Site in Western Wisconsin

Site	Date	Sex	SBR (cm)	SVL (cm)	BT (°C)	BM (g)	No. Rattle Seg
PIE-1	May 23	F	106.7	99.0	30.4	92	8
PIE-1	May 1		91.4			50	8
PIE-1	May 18		61.0				
PIE-1	May 18		53.3	49.5		100	
PIE-1	May 18		76.3				
PIE-1	May 21	F (gravid)	111.8	104.0	30.6	940	
PIE-1	May 21		55.9	50.8	30.5	110	button +1
PIE-4	May 23	M	95.0	87.6	30.4	530	
PIE-4	May 23		92.0				
PIE-6	July 30	F (gravid)	101.6		33.6	834	
PEP-1	May 13		78.7				5
PEP-1	May 13		73.7				
PEP-1	May 18	F	96.5	90.2		510	6
PEP-1	May 23		35.5		30		button only
PEP-1	Sept. 11	M	101.6	93.3	29.1	835	2 (broken)
BUF-1	May 28	M	123.2	114.0	30.2	1110	4 (broken)
BUF-5	June 4	F (dead)	71.0	66.0		395	6
TRE-1	Sept. 3	M	55.9	50.9	21.6	95	button +1
Range			35.5-123.2		21.6-33.6	30-1110	
Mean + SD					29.6±3.5		

SBR = Snout to base of rattle, SVL = Snout-vent Length, BT = Body Temperature, BM = Body Mass

adjacent southeastern Minnesota (Conant 1975). Timber rattlesnakes den in areas of bluffs and steep rock outcrops on south and southwest facing hillsides. They are found near these rock outcrops during the spring and again in the fall. In these northern latitudes this species of rattlesnake requires rock outcrops or bluffs of limestone, sandstone, or dolomite with ample sun exposure. Plants associated with these outcrops and bluff prairies are cedar, oak species, birch, cottonwood, hackberry, sumac species, poison ivy, wild grape, bittersweet, columbine, harebell, puccoon, violet species, wood sorrel, and various grass species. *Crotalus horridus* moves in nearby mixed deciduous forests and agricultural lands during the summer (Vogt 1981). The summer foraging areas need to be in close proximity to the denning areas as this species seldom travels more than 2.4 km from its den (Martin 1966). Adequate ground cover, suitable drinking water, and a stable food supply are provided by mixed deciduous forests of oak species, maple species, basswood, elm, and hickory. While searching for rodents, the timber rattlesnake will also utilize forest edge next to agricultural fields and woodlots.

The range of *C. horridus* has been shrinking and fragmenting across the northeastern United States ever since European settlers began colonizing. Since the turn of the century, wanton destruction of rattlesnakes has occurred in Wisconsin. Our study was prompted by the apparent, but undocumented decline of *C. horridus* in Wisconsin. Historical distribution prior to 1880 is shown in Figure 3 as adapted from Schorger. Figure 1, which was generated by our study, compares favorably with Figure 2, which was adapted from Vogt. Results of our study show that the northern and southern points of distribution along the Mississippi River closely coincide with those reported by Schorger and Vogt. However, inland distribution continues to be of concern. Recent sightings and reports by landowners (personal communication) did not afford any confirmation of present-day inland distribution.

The extreme northern record for *C. horridus* in Wisconsin, as reported by Breckenridge (1944) prior to 1939, came from the

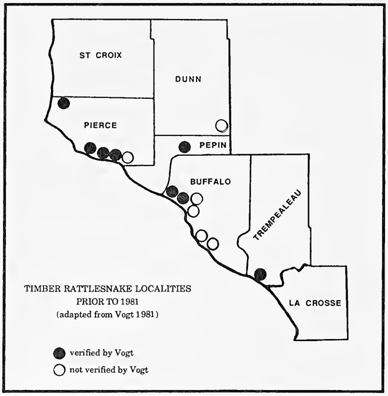

Figure 2

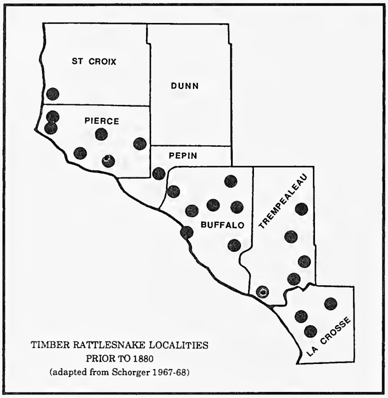

Figure 3

civil town of Troy in St. Croix County. Our study confirmed a population in the extreme northwestern corner of Pierce County (PIE-1) about 8 km south of the Troy record.

Schorger reported sixteen references to localities in six civil towns in Pierce County. Vogt indicated four localities within the county personally verified by him. Our study established localities in five civil towns.

All of Schorger's data from Dunn County refers to massasauga rattlesnakes (*Sistrurus catenatus*), and the single locality in the county submitted by Vogt (1981) was unverified. Time constraints precluded any field work in Dunn County by our study.

Only one *C. horridus* locality was reported in Pepin County by Schorger. This was near the town of Frankfort. Vogt (1981) reported one locality northeast of Frankfort. In our study, a population was found near the Mississippi River in the civil town of Stockholm. We surveyed three additional sites in this county and could not establish the presence of the rattlesnake.

References to seven localities in six different civil towns for Buffalo County exist, and six of these localities are inland. Vogt (1981) map-plotted six sites of which only two were verified by him. We were able to demonstrate the presence of *C. horridus* at three localities in three different civil towns. One inland site was verified by our field work.

We surveyed one site in Trempealeau County, and this was Brady's Bluff in Perrot State Park. The existence of *C. horridus* was verified. Several other sightings were reported by park officials and visitors during 1988 within the park (personal communication, Perrot State Park officials). The park was the only map locality given by Vogt. In addition to the park, Schorger listed four inland sites.

While three *C. horridus* localities have been historically reported in La Crosse County, we were unable to do field surveys in La Crosse County for present-day verification. Martin (personal communication) indicated that he had two reports of sightings of rattlesnakes in La Crosse County in recent years; however, specifics as to species or exact localities were not available.

Evaluation of population densities was not within the scope of our study; however, results suggest that large populations of timber rattlesnakes as reported historically no longer exist. Schorger presented a number of citations in which thirty or more snakes were killed at one time at various locations; and reported that ninety-nine rattlesnakes were killed in 1862 at Gilmanton (Buffalo County) on a rattlesnake hunt (Schorger 1968). We spent 136 actual field hours and located twenty-five timber rattlesnakes from late April through October 1988. This calculates out to be 5.5 field hours per timber rattlesnake encounter. Forty-two site visits produced snakes only sixteen times, or on 38% of the site visits. The largest number of snakes found at a single site visit was five, supporting the theory that large populations no longer exist.

The biological data gathered by our study (Table 3) from eighteen timber rattlesnakes, although incomplete in some aspects, does give useful information. The sex ratio of 4:5 (four males and five females) is approximately 1:1, and suggests no dominant sex ratio. The average body temperature of eight snakes was 29.6°C; this closely approximates the preferred body temperature of other North American pit vipers as reported by Lillywhite (Seiger et al. 1987). A single specimen had a body temperature of 21.6°C, but this animal was found coiled underneath a rock on a cool, rainy day and does not reflect a preferred temperature. An established preferred body temperature for timber rattlesnakes could not be located in the literature.

Recently there has been considerable scientific controversy concerning the validity of the subspecies *C. horridus atricaudatus* (Brown et al. 1986 and Pisani et al. 1977). During the course of the present study two specimens were found with distinct post-ocular stripes, and several displayed obvious mid-dorsal stripes. Both of these characteristics are criteria used to partially describe the southern subspecies. A marked variation in pattern and coloration was observed among the animals studied.

Conservation of the timber rattlesnake has two important facets: habitat preservation and snake protection. Economic incentive threatens habitat alteration of bluff prairies and steep rock outcrops by man and may be an immediate threat to the snake. Land development and residential building sites at the base of rattlesnake hills or on top near dens generally has a deleterious impact on snake populations due primarily to increased encounters with man. Periodically timber rattlesnakes show up in the yards of residents near bluffs in Pierce County (personal communication, Bob Burnett, two reports during the summer of 1988 near Hager City). A golfer searching for golfballs in the rough at Clifton Hollow Golf Course suffered a rattlesnake bite on June 24, 1988 (personal communication, D. Foley, attending physician). Roadkills claim an unknown number of rattlesnakes each year on highways and roads located near *C. horridus* habitat. Land developers continue to subdivide and sell building sites along the bluffs in southern Pierce and northern Pepin Counties. Thus, habitat encroachment by man continues at a substantial pace.

Man's persistent predation of the timber rattlesnake has reduced populations to the point of requiring total legal protection in several northeastern states (Martin 1982). The vulnerability of this species at ancestral den sites makes it an easy target for snake hunters. A bounty system deploys more snake hunters and also increases the chance of snakebite. Nontarget and protected snake species may also be destroyed by indiscriminant bounty hunters. Minnesota had an active rattlesnake bounty until August, 1989. A snake hunter from Buffalo County indicated that snakes could be taken from Wisconsin into Minnesota for payment of bounties (personal communication). Our study data strongly upholds a non-bounty policy in Wisconsin and in fact gives support to total protection of this species. In many states (Connecticut, Massachusetts, Vermont, Rhode Island, New York, New Jersey, Texas, Missouri, and Kentucky) the timber rattlesnake is a protected species (Allen 1988).

The results of our preliminary survey suggest the need for future studies of *C. horridus* in Wisconsin with information needed on remaining inland populations. Surveys should be conducted along the Mississippi River from La Crosse to the Illinois border. Devising a method for evaluating population densities would be extremely valuable for management of the species. Considerable time and effort are required to do rattlesnake fieldwork. Our study consumed 136.25 field hours, 79 travel hours, 20 field days and 3,950 miles. Adequate allotments for time and effort will help to ensure the collection of an adequate volume of data.

The timber rattlesnake is a non-aggressive, secretive animal of steep bluffs and adjacent forests. It undoubtedly plays an important role in biological balance as a rodent predator. The snake has few natural enemies, a low reproductive rate, and a long lifespan (Martin 1966). The timber rattlesnake is a symbol of the wilderness, as is the timber wolf, and should be provided the opportunity for continued survival in the natural world.

Acknowledgments

We would like to give special thanks to Gary Casper of the Milwaukee Public Museum for providing museum records, published information, and interview material from naturalists and snake hunters of western Wisconsin. He also offered technical assistance and encouragement with the project.

Several individuals generously volunteered their time to assist with field surveys. We wish to thank Jim Gerholdt, Del Jones, Tom Keyler, Don Leaf, John Moriarty, and Casey Oldfield. Bob Burnett with extensive field experience hunting timber rattlesnakes in Pierce, Pepin, and Buffalo counties provided us with useful information concerning localities and general hunting advice. He also assisted with field surveys. Dave Lindenrude and Cindy Swanberg of the Wisconsin Department of Natural Resources provided useful locality data. The authors wish to thank W. H. Martin of Harpers Ferry, West Virginia, for distribution information of *C. horridus* in Western Wisconsin. We also are most appreciative for the efforts of Diane Loudon in the preparation of this manuscript.

Finally, we wish to extend special thanks to our wives and families for their support and cooperation throughout the rattlesnake season.

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From Wisconsin Poets

In this, the second issue in which we have featured poetry, all the poets represented are once again from our state. We are particularly pleased that our call for poetry resulted in submissions by poets as well known and admired as Ron Ellis, Mary Shumway, Susan Firer, David Steingass, Ronald Wallace, and Kelly Cherry. We are also pleased to present the work of David Graham and Karen Loeb who are relatively new voices to readers of Wisconsin poetry. We hope the appearance of poetry of such quality and distinction will please our readers and continue to establish *Transactions* as a showcase for poetry in Wisconsin.

About the Poets

***David Graham** is Assistant Professor of English at Ripon College. He is the author of two collections of poetry,* Magic Shows *and* Common Waters. *In addition, his poems and essays have appeared in such places as* Poetry Review, The Georgia Review, Poetry, and College English. *"The Naked and the Nude," presented here, is part of a recently completed manuscript of poems concerning photography entitled* Mirror With a Memory.

***Ron Wallace** directs the creative writing program at UW-Madison. He has published numerous books, and his anthology,* Vital Signs: Contemporary American Poetry From the University Presses, *will be published in August by University of Wisconsin Press. His work has also appeared in* The New Yorker, The Atlantic, The Nation, Poetry, *and elsewhere.*

***Mary Shumway** teaches at UW-Stevens Point. Her poems have appeared in a variety of journals including* Denver Quarterly, Northeast, Prairie Schooner, *and* Wisconsin Academy Review. *Her next manuscript is to be published by Juniper Press.*

***Kelly Cherry** is the author of seven books, most recently* Natural Theology. *She has been awarded numerous fellowships and two PEN Syndicated Fiction Awards. The Fellowship of Southern Writers has just named her the recipient of the first Poetry Award, which is given in recognition of a distinguished body of work. She teaches at UW-Madison.*

***David Steingass** lives in Madison where he conducts public school writing workshops. His books* Body Compass *and* American Handbook *were published by The University of Pittsburgh Press, while his poems are found in numerous journals. His chapbook,* Homesick for Fox-Blood, *is scheduled to be published in 1990. He is the first recipient of the Paulette Chandler Award from the Council of Wisconsin Writers, 1988.*

***Ron Ellis** teaches writing at UW-Whitewater and edits the poetry journal* Windfall. *He is not only well known for his poetry, but his special interest in performance has gained national recognition. His audio cassette album,* Open My Eyes, *has been favorably reviewed in* The Village Voice *and has been aired on National Public Radio as well as WNCY in New York.*

***Susan Firer,** whose work is published in a number of poetry journals, is the author of* My Life with the Tsar and Other Poems. *She says that the two strongest influences on her daily work are her family and Lake Michigan. Susan teaches creative writing at UW-Milwaukee.*

***Karen Loeb** recently moved to Wisconsin from Florida. She has published fiction, poetry, and non-fiction in numerous journals. Her recent stories are found in* The South Dakota Review, Korone, Footwork, *and in* New Visions: Fiction by Florida Writers. *Two of her stories have received PEN Syndicated Fiction Awards and appeared in participating newspapers.*

The Naked and the Nude
—three photos by Imogen Cunningham

1. Side, 1930s

A side of what? It could be flesh, could be
some twisted glove or over-ripe pepper.
If flesh, male or female? Does it matter?
Only bent leg, rippled skin, and curving edge
of spine survive the cropping. Neither naked
nor nude, these whorls and eddies of torso,
textured like rock, water, sand in shadow,
even a hint of scar part of the design.
(In my book a banana plant bristles
on the opposite page, though without label
it could be rumpled foil, or farmland
from an airplane.)

Looking closer, I see
how nothing but living skin shines this way,
curled for the naked eye to judge, easy to love
as a meal. Anonymous and true,
flesh consumed with or without label.

2. Two Sisters, 1928

No doubt it was fashion to crop their faces,
as if to show photography can mimic
the headless heroines of ancient Greece.
Yet if they are no more than light and form,
why the title? For as they are sisters
they are stories, and as they are stories
they blur and fade, they will not sit still.
Are they twins? Do they enjoy being nude
together before this accurate eye?
Can form be beautiful without content?
And if their goose bumps, their moles, and the hair
between their legs are not beautiful,
then the eye is false witness to the heart.

Half a century later, these women
may still live. Imagine eighty-five year old twins
sharing an apartment in Florida,
sleeping in the same bed, taking baths,
always nude, always together,
their changed bodies still mirror images.

Even if she only exists before
I was born, a nude woman interests me,
but any sister would know we are best
unobserved, loveliest seen through the eyes
of self-fulfilling love. This photograph
has love in it, more than most, but no one
could wholly love these women and still see.

3. Triangles, 1928

Clouds, leafy shade, the long roll of water
between wind and stone, mirage of desire:
mother-triangles in the rectangle
of art. Light and dark, light and dark again,
until the thing comes right, becomes word
without turning to statement, becomes nude
open to light, casting shadows herself
on herself, softness created by light
more than by smooth belly, nipple, and thigh,
and all folded into triangles, yes,
like a mother folded around her daughter
yet to be born, yet to be conceived.

David Graham

Winter Strings Concert

Dwarfed by cellos,
violins and violas stuck under chins,
arms and legs akimbo, they grin
out at the audience. *Please,*
says the teacher, as one Japanese
boy leaves weeping, jabbed by a bow,
this can be dangerous.
My daughter, shy in her finery
mouths *Father, go home,*
as I lip read.
And they're off! Cellos grumbling,
violins squeezing the lemony air,
from Humoresque to Hot Cross Buns,
from Jelly Roll Blues to Jingle Bells,
from the Halls of Montezuma to
the Shores of Tripoli
they trill inexplicably, solemnly
gazing into space as if
they were anyplace else but here,
hamstrung in sound,
each instrument wandering off
on its own lonely inventions.
Until, measure by measure
the years collapse,
and crescendoed with tears, I'm back
in my own gradeschool gymnasium,
the future a symphony
warming before me, furiously
sawing my way out of childhood,
playing the dangerous music of nostalgia
to the roar of improbable applause.

Ronald Wallace

In the Sculpture Garden

Ernest Trouva's "Poet"
in his cloak and rakish hat
sits flat beneath his flat black tree,
mere silhouette, mere shadow
among the dying elms and maples.
Edging the wrought-iron woods,
"Three Women Poets,"
arm in arm, and stiff as nuns,
walk in place.

A hundred years ago
they'd not have worn
this black absence of our imagination
as they met and talked
Rimbaud and Baudelaire
in those flamboyant hours
when everything was possible.
Where is the gaudy eloquence?
Where the bluff and strut?

This is no time for poets.
On the near horizon
oil drums loom red and magenta—
toppled, tubular stacks.

What Easter Island of the mind,
what Stonehenge of the soul
will some unimaginable future
make of this
which baffles even us?

Meanwhile, Garnett Puet's bees,
mistaking a wax-filled plywood box
for a hollow tree,
are busy sculpting
a woman out of honeycomb.
Bees in eyes and nipples.
Pubic hair of bees.
We watch like drones.
We glance furtively back.

Ronald Wallace

Mr. Evans' Oracle: Sally Rand Vacations in the Dells

They cut and harvested more than usual that winter
but the icehouse was almost empty. Kids
no longer played among the blocks nested
in straw to escape the stubborn sun. Lids

of tarp, lowered as the ice was sold or melted,
couldn't mold, even dried by midday in that sun-
dogged and long July. The men grumbled,
thumbs in their overalls, long after they'd won

their bets—or lost—on rain that never came.
Thomas shuffled toward the door. "It's low,
perilous low," he mumbled. They all knew what
he meant, and Thomas would be first to go

when the rest was sold, probably in August.
Hans remembered, and to cheer him said,
"You better find a bench downtown today,
Mr. Evans. A certain dancer's here to spread

her feathers." "Or shed 'em," Lambert added
with lust he summoned only for the rain
and the river's rise and the early cold to make
ice enough to last through fall, and plain

hearty meals regular as pay allows
until the winter harvesting again. He grinned,
a little thin though, and Evans' face frowned
into a pending storm announcing Lambert sinned

to pass such news. It was nothing to him. Nevertheless,
without a backward glance he turned toward town
and found a bench unoccupied by sun, one
at least he wouldn't stick to, and settled down

to watch the traffic at the ice cream stand
across the street. The icehouse kids, adrift
among the tourists, pigtailed to the counter
where flavors melted to a ribboned gift

of possibilities. Two scoops for a nickel,
and nickels rarer than this summer's rain,
choice amounted to responsibility—
dark, heavy as a man's long pain

of idleness. And then a shadow passed.
Thomas stirred and frowned into the sky.
Above the glass and unrelenting blue,
plumes of mare's tails splayed—too high

for shadow. But low across the hills, atilt
as Bessie's cones, scoop on scoop, clouds
piled. The children's voices dropped, their eyes
and mouths round with awe. He saw crowds

cleave and gather as Sally stole the show
amid grins and consternation paired
imperfectly. The icehouse kids even feathered out
around, deft as her fabled fans, and stared.

They never saw the clouds. Sally played
their spellbound impudence, her walk a game
that out-maneuvered fans with grace of one
who knows her house, her claim of space, her fame.

Well, dour old Thomas, caught between
those feathers high and low, rose and pranced
adrift uncertain air that freshened with the lift
of bright and tendered promises, and danced.

Mary Shumway

The Final Visit With Her Brother

She remembers the drafty rooms,
    the front lawn where mud blooms,

how he lay there, legs like sticks
    of kindling, drinking six-

pack beer or "tonic water."
    My eye. Later,

how he insisted on standing and taking her
    in his arms, after making clear

how deeply he felt she'd let him down,
    and said he loved her anyway, but soon

she pulled away, feeling caught
    in the embrace she had fought

so hard to free herself from,
    and he lay back down on the bed and said, "Come

again, you hear?"—softly mocking
    the Southern sense of what is kindly, what is shocking—

and turned the TV on again,
    the black-and-white portable, when

she left, as if denying—
    oh, everything.

Kelly Cherry

Portrait in Blue and Red

Her nerves were shot.
Dr. Fear had paid her a housecall.

After he left, she stood alone in the hall
As if expecting the front door to burst open,

Someone to come in like Jack Nicholson
With a knife in his hand.

In the mirror above the blue china bowl on the marble stand
She saw a small girl jumping rope.

(The apples in the bowl were ripe,
Radiating redness.) When she was five,

She'd loved being alive,
Wearing her hair in pigtails, jumping rope,

But already, she could see, she'd been desperate, and losing hope.

Kelly Cherry

The Margin For Loss

To live through winter
we need to see our best direction
lost in snow. Then ambition finds

each of us alone. We recognize
what once we turned our backs on
we'd leave home for. We feel wind

shape our thoughts, and find owls
crouched inside dark pines. Their eyes,
a constellation's cold fire,

lead us away. We name zero
the margin of error, total
the margin for loss.

David Steingass

Front Door Open

sunlight untouched by glass
          air   we'll take raw

step out
          talk about
picking up the yard

redwings
          crows
                    cranes

until a silence
a spreading   attention
the shadow
          swoop
                    red-tailed hawk

a sudden remembering

                    until the first
                      redwing call

Ron Ellis

Easter Sunday Afternoon

Aunt Virginia sleeps two sheets to the wind
upstairs in the martini spinning bed.
She has once again drunk the children's
Easter bubbles and removed
her wig with her bonnet.
Easter lamb fragrance,
white coconut covered lamb cake.
One snowy spring years ago
the Dusenberg of death drove Edward,
her only husband, away on a snow
blowing Sunday. Only his glasses
and Sunday Journal left behind
on their marital bed. Once widely traveled
heavily jeweled, when young chauffeured
Virginia became a proofreader on the
Milwaukee Journal. "Never trust
the advice columnist," she warned
me when I was ten. "I've shared
the lavatory with her, never washes
her hands when she's finished."
Many bridge games and a half dozen
well fed and collared dachshunds later
Virge rests upstairs. God bless all
childless Aunts who give themselves
to unappreciative nieces and nephews,
take them to plays, buy them books,
or like Virge bought me when I was ten:
a leopard skin coat and garnets.
God bless all, but especially
Aunt Virge whose keys are once
again locked in her baby blue T-Bird.
We're going through the trunk for them
this Easter. Wish us and her luck.

Susan Firer

Stirring

"Always stir
from left to right,"
my mother said
moving the wooden spoon
through the chocolate pudding.

After all
Grandma stirred
from left to right.

Something to do
with gravitational pull
maybe the moon
and the tides.
Who knows
what unseen forces
have caused people to stir
from left to right.

"It's why the clock goes
from left to right,"
she said
tapping the spoon on the pot
like a metronome.

I never wondered
why the clock
didn't go the other way
never thought it was
related to stirring.

My father too
knew about this stirring.
I found him at the stove.
He held the spoon
differently than my mother
but he stirred
from left to right.

If you're stirring something,
can't remember the direction,
think of the clock
and the way it knows to go.

Karen Loeb

The Role of Plant Root Distribution and Strength in Moderating Erosion of Red Clay in the Lake Superior Watershed

Donald W. Davidson, Lawrence A. Kapustka, and Rudy G. Koch

Abstract. *Erosion of the glacially derived red clay soils in the western Lake Superior Basin is a serious problem and has been known to be a problem since the settlement of western Lake Superior lands. We investigated the influence of plant root systems on erosion of the red clay soils. Measurements of the rates of surface erosion and of deep-seated slope failure (slumping) were made between August, 1975, and June, 1978. Slope failure as monitored along transects was greatest in areas with sparse trees or herbaceous cover. The most stable area had a dense tree cover along with a dense understory of* Corylus cornuta *and* Cornus stolonifera. *The estimated soil loss (mton · ha*$^{-1}$*) during the period 15 May through 15 October 1977 was stable grassed area, 0.2; grassed areas experiencing slumping, 7.8; stable wood areas, <0.1; wooded areas with slumping, 0.4. During the same period detailed measurements of vertical root distributions, root tensile strength, and vegetation cover along and adjacent to stream banks were obtained. Roots were excavated from 36 quadrat sites adjacent to 8 of 12 transects established to quantify slumping of soils. The excavation of 0.2 m*^{2} *quadrats was accomplished at 10 cm intervals to a depth of 50 cm. All roots obtained from the excavation were sorted according to 12 diameter classes to determine total root mass and calculate total root length. Essentially all roots occurred in the upper 50 cm of clay soil, and 50% of the root mass occurred in the 0–10 cm zone. The tensile strength of roots less than 2 mm diameter of selected species was determined for 5 cm segments of roots. The tensile strength of small fresh roots (less than 1 mm diameter) was 1.5–8.5 times greater in woody species than in herbaceous species. Among woody species, later successional species characteristically had stronger roots than early successional species. Collectively these data indicate that vegetation comprised of woody, advanced successional species afford the best protection against both surface and deep-seated stream bank erosion.*

Vegetation effectively reduces both surface erosion and subsurface slumping by intercepting and reducing the velocity of precipitation and retaining soil particles and reinforcing soil structure (Penman 1963). Among the most significant features in this regard are (*a*) an increase in the shear strength of soils as a result of reinforcement by roots and (*b*) soil arching, the transfer of stress across a potential failure surface in the soil (Gray 1976).

Significant correlations between tree cover and slope stability have been developed in several field studies (Gray 1973, 1974; Marsh and Koerner 1972; Bishop and Stevens 1964;

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Anderson 1972). Swanston (1970) found an apparent soil cohesion and shear strength caused by roots that is not reflected by the physical properties of Karta soils in southeastern Alaska. His study of root deterioration following clear cutting indicated that the contribution by tree roots to soil shear strength diminished within three to five years. This decline coincided with the observed time lag for landslide acceleration following timber harvest. DeGraff (1979) further distinguished the relative advantages of various vegetation types with respect to erosion. His work identified increased landslide activity when tree and brush cover was converted to grassland cover. The apparent causes were a concomitant increase in soil moisture and a reduction in the consolidating root network.

The erosion of red clay, a source of natural pollution of the south shore of Lake Superior, has been a problem since the last glacier receded (Mengel 1970). This erosion has had an impact on the ecology of the Lake Superior waters. The physical parameters of the red clay loading of Lake Superior have been studied in detail by Oman and Sydor (1978), Diehl et al. (1977), Sydor et al. (1978), Stortz and Sydor (1980), and Sydor et al. (1978). These workers dealt mainly with red clay contaminants in Lake Superior through Landsat 1 data, and turbidity dispersion in Lake Superior and in the Duluth-Superior harbor, through use of Landsat data. Stortz (1976) pointed out that "western Lake Superior is characterized by clean water periodically contaminated by the red clay particles, originating mainly from glacial-lacustrine deposits along the shores of Douglas and Bayfield counties, Wisconsin . . ."

Chemical loading was also examined by Bahnick et al. (1972), Bahnick et al. (1978), Bahnick (1977), and Bahnick et al. (1979). These studies focused on nutrient loading, especially orthophosphates, into southwestern Lake Superior. They reported up to 240 mtons of soluble orthophosphate from soil entering Lake Superior annually from shoreline erosion and 63 mton from river particulates (Bahnick 1977).

Swenson (1978) studied the influence of red clay turbidity on fish abundance in western Lake Superior. He found that light penetration in western Lake Superior is reduced significantly even at very low concentrations of red clay turbidity.

Although plant properties related to erosion abatement are accepted generally, the relative contributions of each applied to a specific problem are speculative. We have sought to define the capacity of vegetation to moderate erosion of the red clay zone of western Lake Superior. These investigations have had three main thrusts: (1) the description of the vegetation, presettlement and contemporary; (2) the influence of the vegetation on soil water content and the susceptibility to erosion; and (3) the distribution and strength of plant roots in the region. Our studies reported here describe the relationship of surface erosion and slumping with the distribution and strength of roots of selected species and vegetation types. Our hope is that slumping of red clay soils may be retarded by working with plants that have stronger roots.

The soil types encountered in the drainage basin of western Lake Superior fall into four general types: red clays, loam upland soil, northern sandy soil, and alluvial soil (Hole 1976). The red clay soils of the Superior plain consist of clays of glacial-lacustrine origin that are predominantly of the montmorillonite type, with small quantities of illite, chlorite, and kaolinite (Andrews 1979; Hole 1976). The characteristic red color results from extractable iron oxide that constitutes approximately 2% by weight. Lenses of unsorted sands, gravel, and cobble are encountered frequently in the otherwise uniform clay. The clay fraction has a bulk density (g cm^{-3}) of 1.05 + 0.10.

Several physical properties important in maintaining are influenced by the moisture content. At typical sites, especially below the root zones, moisture content ranges between 40% and 50%. Field capacity of the upper 15-cm zone generally approaches 55%, while the permanent wilting point is around 12%

(Kapustka et al. 1978). The plastic limit (the brittle solid state) ranges from 20% to 330%, while the liquid limit (fluid state) is 40–80%. Upon wetting, the dry clay swells to 120–140% of the original volume (Mengel and Brown 1976a, b).

The mechanical strength of soil of the red clay region is determined primarily by the montmorillonite fraction. Slow-rate triaxial shear tests indicated failure of soil slopes at 18–200. Natural slope angles, however, appear to be stable around 100. The cohesion of the clay changes from 0.05 kg cm^{-3} near the surface to 0.35 kg cm^{-3} at depths of 25 m (Mengel and Brown 1976a, b).

Methods

Erosion by Slumping

Field sites were selected in August 1975 to monitor slumping activity at ten locations in the Little Balsam Creek and at twelve locations in the Skunk Creek sub-basins of the Nemadji River Basin in northwestern Wisconsin and east-central Minnesota (Fig. 1). The vegetation of the transects represents a diverse cross section of the major types present in the Nemadji Basin. Four principal types are apparent: (*a*) hardwood forest dominated by *Populus tremuloides* Michx.; (*b*) coniferous forest dominated by *Abies balsamea* L.; (*c*) mixed hardwood coniferous forest with varying amounts of *P. tremuloides, A. balsamea, Betula papyrifera* Marsh, *Picea glauca* (Moench) Voss, and *Quercus macrocarpa* Michx.; and (*d*) grassed areas (dominated by *Phleum pratense* and *Festuca* sp.). Each transect extended from the hilltop above the creek to the stream bank along a compass direction approximately perpendicular to the stream. A series of 50 cm long stakes were driven approximately 35 cm into the ground, above and below breaks (cracks) in the soil surface in areas where breaks occurred and at regular intervals where there were no apparent failure zones. A variety of vegeta-

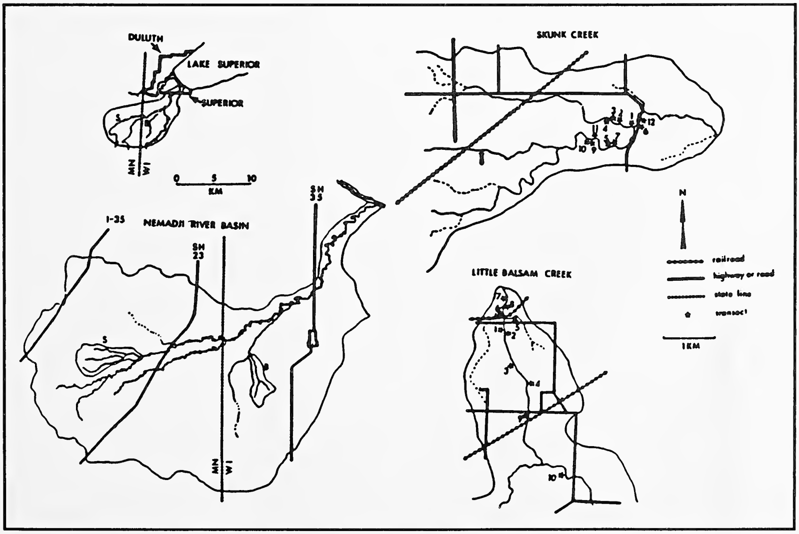

Fig. 1. Location map of Skunk Creek and Little Balsam Creek transects.

tional types was selected for the transects with *P. tremuloides, A. balsamea, B. papyrifera,* and grass cover, as well as bare soil represented. The difference from the base point at the top of the transect to each of the downhill stakes, as well as the distance between each of the adjacent stakes, was measured between 7–22 August 1975, 1–8 November 1975, 16–22 April 1976, 14–21 October 1976 and 12–23 May 1977, 5–11 August 1977, 12 November 1977, and 21–23 June 1978. Distances between stakes were recorded to the nearest 3 mm.

The precision of the transect stake measurements was determined by repeated measurements of Little Balsam transect no. 9. This transect was judged to be as difficult as any to measure due to topographic and vegetational features. Five replicate measurements were performed, and the standard deviation was used to calculate the 95% Confidence Interval for the values measured. The precision of the between-stake distances was 1.7 + 2.0 mm, while the precision of measurements from the crest to each stake was 2.9 + 1.7 mm. Based on these values, we conservatively judged that differences in measurements between sample dates greater than 6 mm indicated movements of the stakes rather than errors in measurements. Differences of less than or to equal 6 mm were ignored in our calculations.

Vegetation Cover of Stable and Slumped Sites

To compare the vegetational cover of stable and slump sites, quadrats were randomly placed in slumped sites and adjacent stable areas with similar physical features. All trees within a 10 m^{-2} area were tabulated and their diameter at breast height measured. In addition, all shrubs within a 5 m^{-2} plot nested within the tree quadrat were counted. All herbs within a 0.25 m^{-2} quadrat randomly placed within the larger tree quadrat were clipped at ground level, field sorted to species, and dried to constant weight. The dried weight was recorded as phytomass. From these data, relative dominance, relative density, and relative frequency for each species was calculated and used to derive the importance percentages.

Surface Runoff

Four sites in the vicinity of Little Balsam Creek (transects 5 and 8) were chosen to represent (1) tree cover—stable; (2) tree cover—slumping; (3) herbaceous cover—stable; and (4) herbaceous cover—slumping.

At each site five enclosures (1 m wide and 2 m long) characterized by different slope gradients and representative cover were constructed to monitor surface erosion during 1975 and 1976. The perimeters were defined with galvanized metal roofing, partially buried leaving as approximate 115 cm-border above the soil surface. A polyurethane border was added between the metal and the ground surface to ensure a proper seal. At the base of each enclosure, the surface runoff was collected in 20-l polyethylene carboys. A 140-l plastic garbage can was connected as overflow reservoir from the 20-l container. After each period with greater than 5 mm of rain, the volume of runoff was recorded. A 100-ml sample was filtered through a 0.45 um millipore filter system, and the dry weight of the suspended solids trapped on the filter was determined.

Root Distributions

Excavation sites for determining root distribution patterns were located adjacent to eight of the twenty-two transects established to quantify slope movement. Up to five sites (0.5 m wide x 1.0 long x 0.5 m deep) were selected from each transect to reflect the possible variation in soil and vegetation environment from the crest to the valley. Long was placed down-slope. At each site the following measurements and/or samples were taken:

1. The 0.5 m^{-2} quadrat served as the center for a larger quadrat (10m^{-2}) in which

a complete census of trees (greater than or equal to 10 cm dbh—diameter at breast height) was conducted. The following information was recorded for each tree: (*a*) species identifications; (*b*) geometric position from the center of the inner quadrat; (*c*) dbh; and (*d*) approximate canopy height.

2. Sapling and shrub counts were taken within a 5 m^{-2} quadrat concentric with the excavation quadrat.

3. The living herbaceous vegetation within the 0.5 m^{-2} quadrat was clipped at ground level and brought to the laboratory where it was sorted as to species or general growth forms when taxonomic separation was difficult. Subsequently, the phytomass (oven dry weight) was determined for each identifiable group.

4. The litter within the 0.5 m^{-2} quadrat was collected and treated in the same manner as the herbaceous cover.

5. Soil and root samples were obtained.

The excavation of the 0.5 m^{-2} quadrat was done in 10 cm increments. The visible root material within each 10 cm level was collected and brought to the laboratory. Adhering soil particles were washed from the roots. Subsequently, the roots were sorted into 12 size-classes based on root diameter (cm): less than 0.5, 0.5–0.99, 1.0–1.99, 2.0–2.99, 3.0–3.99, 4.0–4.99, 5.0–5.99, 10.0–14.99, 15.0–19.99, 20.0–24.99, and greater than 30. Oven dry weights of the roots were determined for each size class.

The soil from each 10 cm level was thoroughly mixed in the field, and a subsample (approximately 2 kg) was brought to the laboratory to extrapolate the total quantity of roots remaining in the soil. The roots in the subsample were carefully removed and sorted into diameter size classes. The mass of the roots from the subsample was adjusted by a multiplication factor (mass of soil excavated/mass of subsample × bulk density of the soil).

The relationship between root length and root mass was determined for roots less than 5 mm diameter (Table 1). These relationships were used to obtain an estimate of root length as a function of root mass. The length of roots greater than 5 mm diameter were measured to the nearest cm. The root distribution data for each sample therefore consist of (*a*) the measured mass of roots retrieved from each depth of each hole; (*b*) the measured mass of roots retrieved from the corresponding soil subsample; (*c*) the measured length of roots greater than 5 mm diameter; and (*d*) the calculated length of roots less than 5 mm diameter.

Root Tensile Strength

Roots of selected species were excavated in the field. To ensure proper identity, only roots that could be traced back to the stem of an identifiable shoot were used. The excavated roots were kept moist and brought into the laboratory where the adhering soil particles were washed away. Immediately after washing, the roots either were prepared for measurement of tensile strength or were preserved in a solution of 8 parts isopropyl alcohol and 1 part formaldehyde (Burroughs

Table 1. Length-weight relationships for small roots

Size class diameter (mm)	$\bar{X} \pm t_{05} S_{\bar{x}}$ ($cm \cdot g^{-1}$)	$S_{\bar{x}}/\bar{X} \times 100$
< 0.5	1270 ± 120	3
0.5–0.99	298 ± 34	4
1.0–1.99	94 ± 14	6
2.0–2.99	40 ± 4	4
3.0–3.99	19 ± 2	4
4.0–4.99	13 ± 3	7

and Thomas 1977).

Roots having a generally uniform diameter were cut into segments approximately 7–8 cm long. One end of the root was secured in a rubber clamp attached to an Ametek force gauge; the end was clamped to a rubber clamp handle so that precisely 5 cm of root was exposed between the clamps. The root was subjected to a continually increasing force until breakage occurred. If the break occurred within approximately 2 mm of either clamp the data for that segment was discarded. Otherwise the tensile strength was recorded along with the average diameter of the segment obtained from three measurements made with vernier calipers. Approximately 75 determinations of tensile strength were made for each plant excavated. A log-log transformation of the tensile strength and diameter provided a linear distribution of the data. Subsequently, linear regression analysis was performed expressing the log tensile strength as a function of the log root diameter. No apparent differences in tensile strength between fresh and preserved roots were observed.

Additional measures of root tensile strength were obtained from plants grown under greenhouse conditions on flat surfaces. Seeds of *Bromus inermis* Leyss, *Coronilla varia* L., *Festuca arundinaceae, F. rubra, Lolium perenne, Lotus corniculatus* L., *Poa pratensis* L., and *P. tremuloides* were planted in red clay soil in boxes 15 cm in depth. Except for *P. tremuloides,* plants were harvested after seed set had begun.

Results and Discussion

Soil Slump Erosion

From the time of installation of the stakes, observations were taken at seven seasonal intervals over the 34-month period: I) August 1975–November 1975; II) November 1975–April 1976; III) April 1976–November 1976; IV) October 1976–May 1977; V) May 1977–August 1977; VI) August 1977–November 1977; VII) November 1977–June 1978. The summary of slumping as determined from between stake measurements indicates considerably more slumping activity occurred during periods II and VII than the other five periods. This is apparent in the number of transect intervals exhibiting displacement, the magnitude of individual displacements (both maximum displacements and the net displacement along the transect). During period II all 22 transects had net displacements of greater than 3 cm. In period VII all of the Skunk Creek sites and three of the Little Balsam sites had displacements greater than 3 cm. Periods I, III, IV, V, and VI had, 6, 14, 16, and 4 transects with greater than 3 cm respectively.

Significant soil movement occurred over the 34-month period with a maximum displacement of 2.02 m in Skunk Creek Transect 11 and 1.05 in Little Balsam Creek Transect 8. Seven other transects had greater than 30 cm elongation. In addition, Skunk Creek 11 and Little Balsam Creek 8 lost a total of 1.5 and 2.9 m of stream bank during floods of 1976, 1977, and 1978.

Three general types of soil movement are apparent in the data: (1) overall elongation of the transect (positive displacements); (2) overall compression of the transect (negative displacements resulting from the crest setting); and (3) combinations of positive and negative displacements relating to the ridge top (Fig. 2).

During the periods of higher activity most of the movement led to a general elongation of transect, while periods of lesser activity tended to have both positive and negative displacements. It is likely that both types were present even in the periods of higher activity but were masked by a general downward slippage.

Although the influence of freeze-thaw is generally considered to be a major stimulus to trigger slumping, our data suggest that soil moisture conditions may be equally critical. Our maximum activity occurred in the springs of 1976 and 1978. In both periods the soils were at or near saturation. The soils in the

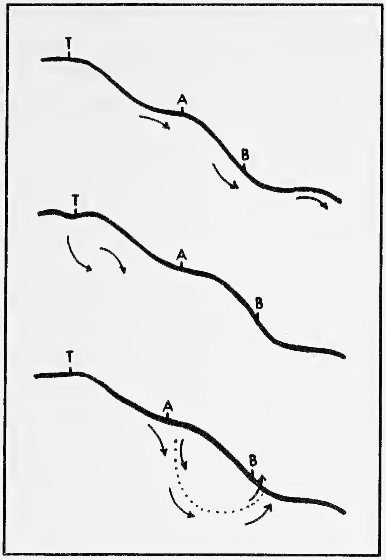

Fig. 2. Scheme of three types of slumping activity to account for (1) elongation of the transect, (2) compression of the transect, and (3) coupled internal positive and negative displacements, i.e. rotational slumping. A and B represent measurement stakes.

spring of 1977 were quite dry, and there was relatively little slumping.

Though several factors interact to affect erosion, the type of cover appears to be closely related to the magnitudes of slumping. The maximum displacements occurred in Skunk Creek 11, which is treeless, Little Balsam 6, a grassed slope, and Little Balsam 8, a sparsely covered *P. tremuloides* area. *P. tremuloides* covered sites exhibited a wide range of erosion activity. Generally, the moderately dense *P. tremuloides* areas having an understory with hazel (*Corylus* spp.) appeared to be more stable than stands with a less developed shrub layer. The mixed conifer-hardwood stands also appear to be correlated with greater stability.

Vegetation Cover of Stable and Slumped Sites

The results of cover analysis of vegetation on slumped and stable sites are recorded in Table 2. The slumped sites tend to be characterized by equal to slightly greater amounts of *P. tremuloides* and conifers than stable sites and with lesser amounts of *B. papyrifera*. In addition, the shrub layer of the slumped sites support lesser numbers of beaked hazel (*C. cornuta* Marsh) and dogwood (*C. stolonifera* Michx.) species which have higher tensile strengths.

Surface Runoff

Following the installation of the surface runoff enclosures a total of 29 rain periods were monitored during the late summer of 1975 and summer 1977. Our system was not suited to handle the spring melt runoff. Consequently, the runoff and sediment valves we report are applicable for summer conditions only.

The volume of runoff in areas with slumping was considerably higher than in stable areas for both grassed and wooded areas and tended to increase logarithmically with increasing amounts of rainfall, as is shown in Table 3. In both grassed and wooded areas the amount of runoff from the stable soils appears relatively high in the greater-than-60-mm-of-water category. Only three rains of this magnitude were recorded, and two occurred after the soil surface had frozen and leaf fall begun. Other than these three rains, the volume of runoff between the wooded and grassed areas is remarkably similar.

The sediment load was extremely variable, especially in the grassed areas. Again major differences are apparent between the slumped and stable areas. The major differences occurred between the grassed and the wooded areas with approximately 10–20-fold or more sediment in the runoff from the grassed areas. The estimated soil loss (mton $\cdot$ ha^{-1}) during the period 25 June–4 October 1976 was stable grass, <0.1; slumped grass, 1.7; and slumped woods, 0.2. During the period 15

Table 2. Comparison of major (I.P. values > 5.5) species of vegetation on slumped and stable sites, Nemadji River Basin (n = number of quadrats)

	Importance Percentage	
Taxa	*Slumped (n = 21)*	*Stable (n = 18)*
Trees		
Populus tremuloides Michx.		
Quaking aspen	46.2	42
Abies balsamea (L.) Mill.		
Balsam fir	39.7	30.3
Picea glauca (Moench) Voss		
White spruce	7.6	—
Betula papyrifera Marsh.		
Paper birch	6.5	19.5
Shrubs		
Populus tremuloides Michx.		
Quaking aspen	11.7	10.6
Abies balsamea (L.) Mill.		
Balsam fir	8.8	8.6
Diervilla Lonicera Mill.		
Bush honeysuckle	8.7	—
Corylus cornuta Marsh.		
Beaked hazel	7.5	15.2
Rosa sp.		
Rose	6.9	7.4
Cornus stolonifera Michx.		
Red-osier dogwood	5.1	12.7
Herbs		
Fragaria sp.		
Strawberry	9.0	—
Equisetum sp.		
Horsetail	7.8	—
Carex sp.		
Sedge	5.9	5.4
Aster marcophyllus L.		
Large leaf aster	5.2	21.5

Table 3. Summary of surface runoff data $\bar{X} \pm S_{\bar{x}}$ for 5 replicate plots for 1976 and 1977. (The amount of rainfall during the monitoring periods for 1976 in 8 rain periods was 162 mm and for 1977 in 21 rain periods was 686 mm.)

			Total runoff Liters ($L \cdot m^{-2}$)		*Total sediment ($g \cdot m^{-2}$)*		*Conductivity[2] (umhos)*	
	% Slope	*% Cover[1]*	*1976*	*1977*	*1976*	*1977*	*1976*	*1977*
Grass								
Stable	21.5 ± 1.6	95 ± 4	1.0	58.3	1.1	21.5	96 ± 19	202 ± 15
Slumped	16.1 ± 1.2	26 ± 13	44.6	122.1	172.7	783.8	173 ± 16	195 ± 16
Woods								
Stable	16.9 ± 2.1	94 ± 5	nd	47.0	nd	3.6	nd	144 ± 37
Slumped	30.8 ± 2.8	18 ± 4	13.1	121.9	22.5	38.7	178 ± 10	220 ± 30

[1]Visual estimate includes vascular plant cover, litter, lichens, and bryophytes.

[2]$\bar{X} \pm S_{\bar{x}}$ for the five replicate plots. umhos were used as the measurements for conductivity, rather than SI units, as a conductivity meter was used.

May–15 October 1977 the soil loss was stable grass, 0.2; slumped grass, 7.8; stable woods, <0.1; slumped woods, 0.4.

Root Distribution

The mass and total length of roots within the soil profile were related to differences in vegetative cover and soil texture. On clay soils tree cover tended to have about twice as much root mass as herbaceous cover (Table 4). (Extensive tabular summaries are available from the authors). In addition, the roots from tree cover occurred in a relatively steep-sloped log-linear pattern with roughly 50% of the root mass in the 0–10 cm level. The rooting pattern under herbaceous cover declined very steeply with up to 90% of all roots confined to the 0–10 cm level. Furthermore, the differences in the amounts of roots in the various size classes were dramatic between grassed and wooded areas. Generally in the wooded areas, the less than 0.5 mm category constituted 15–22% of the total root mass. As root diameters increased, the mass gradually diminished per size class. In the predominantly grass-covered Little Balsam 6, approximately 60% of the root mass was distributed nearly uniformly among the four size classes between 0.5 and 5.0 mm. The composition of the two herbaceous cover transects was quite different in both quantity and type of plants. Little Balsam 5 was sparsely vegetated and had considerable amounts of horsetail (*Equisetum* sp.) rhizomes occurring uniformly throughout the 50 cm profile. In the sandy soils roots tended toward a gently sloping log-linear distribution (Tables 4 and 5) but with a greater variance than in the clay soils. From field observations it was apparent that 50 cm depth was sufficient to recover essentially all roots in the clay soils. However, in the sandy soils roots penetrated to much greater depths.

Among the species commonly used to stabilize roadside erosion areas, *Lolium perenne* and *Festuca arundinaceae* produced the greatest above ground phytomass and had 20–25% of their total phytomass as roots and rhizomes (Table 5). *Coronilla varia* produced a relatively good amount of root, but this occurred primarily as a thick tap root. Thus the amount of soil reinforcement was less than for plants with a more diffuse pattern for a similar amount of root mass (e.g., *P. tremuloides,* Table 6).

Table 4. Summary of root distribution data[1]

	Total root mass $\bar{X} \pm S_{\bar{x}}$ *g/plot*	*Mean percentage of total root mass (g) in* 0–10 cm	10–20 cm
Herbaceous cover—clay			
Little Balsam 5	446 ± 108	39	21
Little Balsam 6	578 ± 80	93	4
Combined	512 ± 67	66	13
Tree cover—sand			
Little Balsam 9	872 ± 88	44	18
Little Balsam 10	660 ± 83	34	21
Combined	766 ± 67	39	20
Tree cover—clay			
Little Balsam 8[2]	719	58	18
Skunk 1	824 ± 99	43	18
Skunk 6	1293 ± 382	50	30
Skunk 12	1277 ± 256	57	20
Combined	1124 ± 156	51	23

[1]Bulk density values used for the various soil textures were: sand, 0.95; sandy clay loam, 1.00; sandy clay, 1.05; clay, 1.10 determined previously.

[2]Only one sample excavated at this site.

Table 5. Summary of phytomass production of selected species grown in red clay soil under greenhouse conditions

	Above ground phytomass (g)	Below ground phytomass (g)	Shoot: Root Ratio
Bromus inermis Leyss Hungarian brome	70.3	66.0	1.07
Coronilla varia L. Crown vetch	33.3– 70.0	39.6–81.7	0.85
Festuca arundinaceae Schreb. Tall fescue	246.0–258.4	74.3–75.3	3.37
Festuca rubra L. Red fescue	68.0	8.6	8.0
Lolium perenne L. Perennial rye	213 –215	40.8–79.0	3.98
Lotus corniculatus L. Birds-foot trefoil	34.0– 96.4	15.8–23.5	3.14
Poa pratensis L. Kentucky bluegrass	51.7– 66.9	8.3–10.8	6.21
Populus tremuloides Michx. Quaking aspen	16.1– 42.0	39.0–81	0.46

Root Tensile Strength

Measures of root tensile strength show major differences among woody and herbaceous species (Table 6). Small roots (1 mm diameter) of woody plants were 1.5–8.5 times stronger than of herbaceous plants generally used in roadside stabilization.

The tensile strength of small roots of deciduous woody species may be correlated with the strength of wood as measured by the modulus of rupture. Wells (1976) demonstrated a relationship among numerous morphological features and the successional position of species in the Eastern Deciduous Forest Complex. The modulus of rupture was significantly and positively correlated with advancing successional development.

Representative values of the amounts of rupture (K Pa) for major taxa in our area are *Salix* sp., 33,000; *P. tremuloides* Michx., 35,000; *Fraxinus nigra* Marsh, 41,000; *B. papyrifera* Marsh, 44,000; *Ulmus americana* L., 50,000; *Acer rubrum* L., 53,000; *Quercus borealis* Michx. f., 57,000; *Acer saccharum* Marsh, 57,000; *A. balsamea* (L.) Mill, 34,000; *P. glauca* (Moench) Voss, 37,000; and *P. strobus* L., 34,000 (Forest Products Laboratory 1974). If the relationship between root tensile strength and the modulus of rupture is widespread, then the more advanced successional species can be expected to have the greatest per unit root strength. Our measures of root strength show *A. rubrum* to be substantially stronger than *P. tremuloides* in nearly the same proportions as the modulus of rupture would suggest (Table 6). The conifers do not seem to follow this pattern. *Abies balsamea, P. glauca,* and *P. strobus* exhibit a range of root tensile strength (Table 6) while the modulus of rupture for these taxa are similar.

Root Distribution and Root Strength

High erosion rates are often associated with high amounts of soil moisture. However, due to the special character of the clay with respect to water content, it is not always favorable to maintain low water levels. During the years with normal amounts of precipitation, the soils under all vegetation types tended to remain at or near field capacity throughout the summer. Under these conditions the clay acts as a liquid; therefore the ability of the vegetation to protect against erosion is due to a combination of root distribution and root strength. During the oc-

Table 6. Summary of root tensile strength measures

Species	*Soil Type*	*No. of Specimens*	*Estimated tensile strenght (Kg) from regression equations for given diameters* 1 mm	8 mm
Trees and shrubs				
Abies balsamea (L.) Mill.				
Balsam fir	Clay	4	1.2	98.0
Acer spicatum Lam.				
Mountain maple	Sand	3	2.0	198.7
Acer rubrum L.				
Red maple	Sand	1	3.4	715.9
Alnus rugosa (DuRoi) Spreng.				
Speckled alder	Clay	5	1.2	10.8
Betula papyrifera Marsh.				
Paper birch	Sand	3	0.9	52.4
	Clay	3	1.7	46.3
Cornus stolonifera Michx.				
Red-osier dogwood	Sand	2	1.4	37.0
	Clay	2	2.6	275.2
Corylus cornuta Marsh.				
Beaked hazel	Clay	2	1.8	219.4
Picea glauca (Moench) Voss				
White spruce	Sand	5	1.2	55.9
Pinus Strobus L.				
White pine	Sand	1	1.3	71.5
Populus tremuloides Michx.				
Quaking aspen	Clay	7	1.2	50.9
Ribes sp.				
Currant	Clay	3	1.1	35.5
Herbs				
Bromus inermis Leyss				
Hungarian brome	Clay	1	0.5	nd
Coronilla varia L.				
Crown vetch	Clay	1	0.6	nd
Lolium perenne L.				
Perennial rye	Clay	1	0.4	nd
Festuca rubra L.				
Red fescue	Clay	1	0.9	nd
Lotus corniculatus L.				
Birds-foot trefoil	Clay	1	0.5	nd
Poa pratensis L.				
Kentucky bluegrass	Clay	1	0.6	nd

casional dry year certain vegetation types with high rates of evapotranspiration, such as grassed areas and *P. tremuloides* forests, reduced the soil moisture content to near the permanent wilting point, which is well above the plastic limit for the clay (Kapustka et al. 1978). Under these vegetation types the soil developed extensive fissures often up to 2 cm wide, several meters long, and 15 or more cm deep. Such fissures tend to remain in the soil for years. Thus during subsequent wet periods moisture drains down these openings and promotes deep seated failures below the root zone. When this occurs no vegetation is capable of withstanding the tremendous force exerted on its roots and a block of soil often several meters across slides downhill leaving a newly exposed soil surface. Once initiated, these erosional processes seem to perpetuate indefinitely. The more advanced successional vegetations tend to have a thicker litter layer and a lower apparent evapotranspiration rate and thus prevent the soil fissures from forming even during the dry years.

It appears that root distribution and root strength properties are the most critical vegetation features in reducing both slumping and surface erosion of the red clay soils. Extensive litter cover can be valuable especially as it relates to maintenance of the surface soil moisture. Later successional species tend to provide both more litter and a stronger root system than earlier successional types.

General Conclusions

Our work on the root properties and erosion in the red clay region revealed that

a. essentially all roots occur in the upper 50 cm of clay soil;

b. for similar sites with respect to soil conditions, areas with tree cover tended to have about twice the root mass per unit volume of soil compared to areas with only herbaceous cover;

c. the rooting pattern for wooded sites followed a log-linear relationship for root mass vs. soil depth, with approximately 50% of the root mass occurring in the 0–10 cm zone;

d. on sites with herbaceous cover up to 90% of the root mass was in the 0–10 cm zone;

e. on wooded sites 15–22 % of the total root mass was in the 0–0.5mm diameter size class and as root diameter increased the mass per size class decreased;

f. on herbaceous sites approximately 60% of the root mass was in the 0–0.5mm size class with essentially all roots confined to less than 2 mm diameter;

g. the strength of small roots (up to 1mm diameter) was 1.5–8.5 times stronger in woody species than in herbaceous species;

h. among woody species later successional species tended to have stronger roots than early successional species;

i. vegetation comprised of woody, advanced successional species appeared to offer the best protection against both surface and deep-seated erosion;

j. certain species tended to afford greater protection against deep-seated soil movement than others.

P. tremuloides-dominated sites exhibited a wide range of slumping activity. Generally, moderately dense *P. tremuloides* dominated areas with a well developed shrub understory were more stable, especially when *C. cornuta* Marsh was dominant. Mixed conifer-hardwood stands were also quite stable. Additional data comparing vegetation on slopes with obvious slumping activity to apparently stable slopes revealed an approximate two-fold higher density of trees on the stable sites and higher amounts of *C. cornuta* and/or *C. stolonifera* in the understory. Furthermore, surface runoff rates (mton $\cdot$ ha^{-1}) during May through October 1977 were estimated at 0.2 for stable grassed areas, 7.8 for disturbed grass areas, <0.1 for stable wooded areas, and 0.4 for disturbed wood areas.

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Manifest Details and Latent Complexities in Flannery O'Connor's "A Good Man Is Hard to Find"

Paul J. Emmett

> You might say that [symbols] are details that, while having their essential place in the literal level of the story, operate in depth as well as on the surface, increasing the story in every direction . . . it is from the kind of world the writer creates, from the kind of . . . detail he invests it with, that a reader can find the intellectual meaning of a book . . . the novelist makes his statement by selection, and if he is any good, he selects every word for a reason, every detail for a reason . . . (O'Connor, *Mystery* 71–75).

These passages from Flannery O'Connor's "The Nature and Aim of Fiction" suggest O'Connor's insistence upon the importance of details in fiction. In light of this insistence, it is somewhat surprising that many critics have ignored the evocative details in O'Connor's own fiction. Even the details in "A Good Man Is Hard to Find," O'Connor's most popular short story, have been frequently overlooked. Indeed, in 1972 C. R. Kropf took critics of "A Good Man Is Hard to Find" to task for their tendency to focus almost exclusively on the conclusion of this short story. "The final scene is no doubt a crucial one," said Kropf, "but the story is full of vivid details for which such discussions fail to account" (177–80, 206). And Kropf's indictment was most apt since early O'Connor critics not only focused on the grandmother's climactic "moment of grace," they also tended to discuss broad themes rather than specific details. But by 1981 Hallman Bryant could say that his design was "to shed light on the significance of some small details in 'A Good Man Is Hard to Find' " (301–07), and this is characteristic of the swing toward detail that has taken place since 1972. Robert Woodward has discussed the latent implications of the route that Bailey chooses; James Ellis has examined the apparently inconsequential details of the grandmother's Edgar Atkins Teagarden Story; Frederick Asals has explored the strategic juxtapositions of seemingly unrelated details; Steve Portch has explained "subtle details" related to the grandmother's cat and the Misfit's spectacles; and Bryant himself has demonstrated O'Connor's deft use of place names in this short story (2–5; 7–8; 144; 19–20; 301–07).

So we are moving in the right direction, but still O'Connor's subtle details are even more subtle and detailed than has been supposed. The latent depths in which they "operate" are more complicated, and darker, than has been suggested. As O'Connor herself notes, every word is important and every detail increases the story's depth in numerous directions. "A Good Man Is Hard to Find" has, in fact, the density of dream. And to present this density, to probe the depths, and to penetrate the details I will make frequent use of Freudian theory. I will not be using Freud the philosopher that O'Connor was "against tooth and toenail"; I will be using the other Freud that she had "quite a respect for," the one she saw "bringing home to

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people the fact that they weren't what they thought they were'' (O'Connor, *Being* 110, 490–491). This Freud, who exposes people and depths, can help expose details in ''A Good Man Is Hard to Find.'' And this help is essential because Kropf's indictment—that vivid details as well as the final scene must be taken into account—was not strong enough. The final scene cannot be accounted for until we account for the vivid details that precede it. Statement comes from detail; detail provides ''the intellectual meaning of a book.''

There are, then, many reasons for looking at some of the details in ''A Good Man Is Hard to Find'' before considering the climactic confrontation between the grandmother and the Misfit. These details suggest both the density and the direction of the depths of Flannery O'Connor's fiction, and they lead us to the understanding of both prefatory and ultimate moments. Consider just one example. At Red Sammy's the children's mother plays ''The Tennesse Waltz.'' And it might not be surprising that this small detail has never been considered by critics since the most it seems to do is to add Southern flavor. Yet even if this detail seems obvious, its context demands explanation.

> The children's mother put a dime in the machine and played 'The Tennessee Waltz,' and the grandmother said that tune always made her want to dance. She asked Bailey if he would like to dance but he only glared at her. He didn't have a naturally sunny disposition . . . (121).

Why does Bailey glare at his mother? Why does his mother ask him to dance? Why, for that matter, is selecting ''The Tennessee Waltz'' the only action that the children's mother initiates throughout the entire story? The answers are in the ''obvious'' detail—''The Tennessee Waltz.'' The grandmother had wanted to go to Tennessee, but for once she didn't get her way, and now the mother is rubbing it in. But the mother's attack goes much deeper. As O'Connor says, detail increases the story in many directions. ''The Tennessee Waltz'' is about a woman who steals her friend's sweetheart away. And once we realize this, the context here becomes clearer. At the latent level of the story the mother is saying, ''I'm glad we're not going to Tennessee'' and ''you stole my husband.'' The grandmother counters by asking Bailey to dance, because she knows both the game and the lyrics—''while they were dancing my friend stole my sweetheart away.'' Bailey, in turn, responds with a glare. This son's overreaction suggests his own latent obsession with this unnatural game: most assuredly, he does not have ''a naturally 'sunny' disposition.''

Understanding this one detail does more than help us explicate the scene at Red Sammy's. It suggests the limitations of the common assumptions that the grandmother is superficial but kind, that the children's mother is completely passive, and that the story itself represents a contrast between a happy family and vicious killers. Even as an isolated detail that hints at the jealousies and passions raging beneath the surface of the story, it suggests the striking contrast between surface and depths, manifest and latent. But ''The Tennessee Waltz'' is much more than an isolated detail. It is part of a network of details that reinforce and refine each other as they lead us to ultimate meanings, a network of details that emphasizes and elucidates the latent relationship between Bailey and the grandmother. And since we have to understand this relationship before we can understand the one between the Misfit and the grandmother, we must begin with this network of reinforcing and refining details.

A close look at the accident itself, for example, reinforces and refines the implications of ''The Tennessee Waltz.'' And a close look is necessary since O'Connor's repetition of, and use of capitals in, ''ACCIDENT'' (125, 126) suggest that this accident is more than the automobile mishap that the children revel in.

> Pitty Sing, the cat, sprang onto Bailey's shoulder. The children were thrown to the floor and their mother, clutching the baby, was thrown out the door onto the ground; the old lady was thrown into the front seat . . . (124).

The children are discarded on the floor; the wife, with her baby, is cast out of the front seat, and the grandmother ends up alone in the front seat with Bailey. Again the grandmother takes the mother's place. This is the latent "ACCIDENT" that "destroys" the family, the accident foreshadowed in "The Tennessee Waltz."

Before considering how the accident refines "The Tennessee Waltz," we should note the extent of the reinforcement. The latent accident is suggested with the pairings in the very first lines of the story: John Wesley and June Star are reading on the floor and the mother is feeding the baby on the couch, while the grandmother is with Bailey at the table, showing him both her newspaper and her hip. " 'Now look here Bailey . . . see here, read this' . . . she stood with one hand on her thin hip and the other rattling the newspaper at his bald head" (117). The pairings suggest what the accident and "The Tennessee Waltz" later confirm: the grandmother has taken over Bailey. The details suggest that the grandmother is in the wife's place because she has never relinquished her own place as mother. With hip and newspaper, this temptress and chastiser rattles at bald Bailey. At the latent level they relive the nursery scene. They are stuck in the past, mommy and baby, because the grandmother will not let go. "She wouldn't stay at home for a million bucks . . . afraid she'd miss something . . . she has to go everywhere we go" (118). So Bailey remains "Bailey Boy" (128, 129, 131) and the children's mother is always called "the children's mother." She is never once called "Bailey's wife."

An understanding of the extent of the grandmother's control helps with, and is reinforced by, other subtle details. It's difficult to see, for example, why the children's mother goes calmly to certain death. " 'Lady,' the Misfit asked, 'would you and that little girl like to step off yonder with Bobby Lee and Hiram and join your husband?' 'Yes, thank you,' the mother said faintly" (131). And as manifest explanations come up short (could she be that traumatized?) we turn, almost of necessity, to the latent level where the difficulties fade once we focus on "join your husband." For once the grandmother can't come along; for once—and this is literally the only time—Bailey can be called "husband." In death the family achieves a union that the ever present grandmother has made impossible in life.

Now we can see why the grandmother doesn't really seem to lament Bailey's death until his wife is shot. When Bailey is taken away the grandmother says " 'Bailey Boy!' . . . in a tragic voice but she found she was looking at the Misfit . . ." (128). When Bailey is shot "the grandmother could hear the wind move through the tree tops like a long satisfied insuck of breath. 'Bailey Boy!' she called" (129). But when the wife is shot "the grandmother raised her head like a parched old turkey hen crying for water and called, 'Bailey Boy, Bailey Boy!' as if her heart would break" (132). And the incongruity here is difficult, until we again focus on "join your husband." The grandmother's heart does not break when she loses her son to death; it breaks when she loses him to her hated rival. And to see why the grandmother's reaction is so intense, we must turn to another detail of the accident since the accident not only reinforces the problem suggested in "The Tennessee Waltz," it also refines it by indicating the cause of the problem.

The surface accident, the automobile mishap, is initiated by the grandmother's cat, Pitty Sing, and to understand the latent accident, the family mishap, we must consider the symbolic implications of Pitty Sing. But Pitty Sing is another detail which is virtually ignored by O'Connor critics. Only two have spent any time at all on the grandmother's cat. In 1970, Josephine Hendin asserted that "the cat is too slender of a figure to carry much symbolic weight," and then flawed an otherwise perceptive analysis by discussing the male cat as female. In 1978, Steve Portch recognized the importance of the cat and of the Misfit picking up the cat at the end of the story, but because he did not discuss the "symbolic weight" of Pitty Sing, he could merely assert that the Misfit's gesture is "a moment of unconscious warmth" (150–51;

19–20). So Pitty Sing provides a paradigm of the critical dilemma concerning O'Connor's use of detail. When details are taken too lightly, crucial ones are ignored or misinterpreted. But even with the increasing concern for detail, the ending of the story cannot be analyzed without careful consideration of what Flannery O'Connor refers to in relation to Hulga's wooden leg in "Good Country People" as "accumulating symbolic meaning" (*Mystery* 99). And like Hulga's leg, the grandmother's cat is an exemplary O'Connor symbol: it "operates in depth as well as on the surface, increasing the story in every direction" (O'Connor, *Mystery* 99).

At one level "Pitty Sing" takes us to Pitti Sing of *The Mikado*. This allusion, confirmed by the Misfit's repeated concern that society should "let the punishment fit the crime," reinforces what we' ve learned in the accident since *The Mikado* is about an old man who wants to marry his ward and an old woman, Katisha, who wants to marry the Mikado's young son. At another level, the grandmother's cat is like the grandmother's son. Like Bailey Boy, the cat cannot get free of mother: "She didn't intend for the cat to be left alone in the house for three days because he would miss her too much and she was afraid he might brush against one of the gas burners and accidentally asphyxiate himself" (118). Like "Bailey *Boy*," the cat is rendered puerile by the grandmother's denominations: Pitty Sing is the infantile form of "pretty thing." Like Bailey Boy, the cat is emasculated by the grandmother: Pitty Sing/Pitti Sing/pretty thing. The cat could "accidentally asphyxiate himself," but Bailey is asphyxiated by the accident: both are smothered.

It is, however, Pitty Sing's leap from beneath the smothering hippo's head valise that initiates the accident, and to understand this incident, there is one more level that must be considered. In the accident Pitty Sing is associated with the grandmother: both fly into the front seat; the grandmother ends up catlike "curled up under the dashboard" (125); Pitty Sing ends up grandmother-like "clinging to Bailey" (125). And this is typical since throughout the story subtle details associate cat and grandmother—the grandmother, for example, takes "cat naps" (123). This crucial association is itself reinforced in an earlier draft of the story. "Granny thought that she was the only person in the world that [Pitty Sing] really loved, but the truth was he had never really looked any farther up than her middle, and he didn't even like other cats" (Manuscript). The ambiguous syntax here suggests that Granny is one of the other cats; Pitty Sing's restricted vision suggest that he is associated with Granny's lower half, her animal nature. And although the crude pun on pussy is toned down in the final version, the sexual overtones are still there. Granny hides the cat, for example, because "Her son, Bailey, didn't like to arrive at a motel with a cat" (118).

Pitty Sing, then, increases the story in many directions. Indeed, for the purposes of interpretation there might seem to be too many directions. For example, if Pitty Sing represents Bailey Boy's sexuality, stunted and suppressed, then his leap from Grandmother's basket onto Bailey's shoulder would seem to be a leap to freedom. But how could a leap to freedom initiate the accident: how, that is, could a leap to freedom cause the grandmother to take the wife's place? If, on the other hand, Pitty Sing represents the grandmother's sexuality, potent and primal, then his leap from basket to shoulder would seem to be an attack. But why would the cat then cling to Bailey "like a caterpillar" (125): why, that is, would there be the suggestion of rebirth as a butterfly? To answer these difficult questions and to understand the accident, we must see that these two latent directions fit together because Pitty Sing is both the phallus of Bailey Boy and the phallus of the grandmother. Indeed, he is the phallus that the grandmother now possesses because she has taken it from her son. Pitty Sing is the male rendered female by the grandmother's denomination, but he is also the male under female guise—the lost potency of the son and the dominating potency of the grandmother.

In the drafts, Pitty Sing has a "yellow hind leg," and this fairly transparent phallic image is related to Bailey's yellow shirt because yellow is the point. If Bailey Boy weren't afraid, he could recapture the phallus. This is why Pitty Sing clings like a caterpillar that could become a butterfly: the escape of this caterpillar offers sexuality and rebirth. Bailey, however, can't cope with the cat, and his failure is what actually causes the accident. Pitty Sing springs from beneath the valise that the drafts refer to as "the grandmother's grip" to Bailey's shoulder. But even though the phallus is out from under the "grip" of the grandmother and Bailey should have control, he doesn't. He loses control of the car and causes the accident. Mother replaces wife because Bailey Boy wants both what he should have, the phallus, and what he can't have, the mother.

After the accident, Bailey still has the phallus and, hence, a chance to take charge. "The car turned over once and landed right-side-up in a gulch off the side of the road. Bailey remained in the driver's seat with the cat—gray-striped with a broad white face and an orange nose—clinging to his neck like a caterpillar" (124, 125). The phallus has been turned over once and is now right-side-up, back to its original owner, and as the pause for the parenthetical phrase here emphasizes, "with the cat" Bailey is indeed "in the driver's seat." Even the grandmother cowers: "The grandmother was curled up . . . under the dashboard, hoping she was injured so that Bailey's wrath would not come down on her all at once" (125). But ultimately Bailey wants neither phallus nor control: he flings away the cat, and immediately gets out of the driver's seat.

Like the mythic Attis who castrates himself under a pine tree out of frustrated desire for his mother, Bailey, who tosses the phallic cat "against the side of a pine tree" (125), emasculates himself. And the very next lines of the story emphasize that the cause is frustrated desire for mother.

> Then he got out of the car and started looking for the children's mother. She was sitting against the side of the red gutted ditch, holding the screaming baby, but she only had a cut down her face and a broken shoulder. 'We've had an ACCIDENT!' the children screamed in a frenzy of delight. 'But nobody's killed,' June Star said with disappointment . . . (125).

Bailey's tossing away the cat and looking for the children's mother might for a second seem to be moves in the right direction. Yet, already he's made a few mistakes: he should bring the cat/phallus with him, and he should be looking for "his wife," not "the children's mother." We know, however, that these are not mistakes. Like Attis, Bailey rejects the phallus because he is really still looking for mother, and mother is inaccessible because of the incest taboo. So when Bailey finds his potentially vaginal wife in a "red gutted ditch" (125) he doesn't even talk to her. He merely notes "but she only had a cut down her face and a broken shoulder." And the apparent incongruity in "*but* she *only* had" suggests the ultimate horror. Like June Star, who says, " 'but nobody's killed!' " with disappointment, Bailey looks for his wife in hopes of finding her dead. Only when his wife is completely out of the picture could mother become wife.

Bailey's wife, however, is not dead, and although the grandmother has lost the phallus, she has not lost control over her son. Saying, "I believe I have injured an organ," the grandmother "limps" out of the car (125). Since anyone as well read as O'Connor in mythology knows that a limp is the mythical representation of castration (Jobes 2: 931), these two actions reinforce each other. Since hats have phallic connotations (Freud 5: 1900–01) both actions, in turn, are reinforced by the damage done to the grandmother's hat. "The grandmother limped out of the car, her hat still pinned to her head but the broken front brim standing up at a jaunty angle and the violet spray hanging off the side" (125). The imagery here is particularly telling: although the hat is battered, it is not lost completely. The "violet spray" is "hanging off the side," not gone completely, and this is important since after his emasculation, Attis—who is sometimes hanged on the pine tree—reappears as violets. So the hanging violet spray emphasizes that despite her "limp" the grandmother, who wears another violet spray at her bosom (118), still keeps hold of her castrated Attis.

Without the phallus Bailey ends up lost in the feminine. Sitting in the vaginal ditch, "Bailey's teeth were clattering. He had on a yellow sport shirt with bright blue parrots designed in it and his face was as yellow as the shirt" (125). Since Bailey is as yellow as the cat's hind leg that he has lost, grandmother is quickly back in power. She cuts off the next words that Bailey utters, just as she has "cut off" Bailey all his life. " 'Look here now,' Bailey began suddenly, 'we're in a predicament! We're in . . . ' The grandmother shrieked . . . " (127). O'Connor's deft juxtaposition, "we're in a predicament, we're in the grandmother," emphasizes that the grandmother is the predicament that Bailey Boy is lost in. And Bailey is lost. He does nothing to defend himself or his family against the Misfit. As he is led off to death our final view of him reinforces the problem one last time. "They went off toward the woods and just as they reached the dark edge, Bailey turned and supporting himself against a gray naked pine trunk, he shouted, 'I'll be back in a minute, Mamma, wait on me!' " (128). The recurring image of the pine tree which in myth represents both Cybele and Attis; the details "supporting himself against a gray naked pine trunk"; the first use of "Mamma"; and the fact that Mamma is Bailey's only concern—all tell the latent story. By supporting himself on Mamma and rejecting the phallus, Bailey has castrated himself. In a few moments he will be shot, but at the latent level his impotence and dependence, his inability to act, have rendered him lifeless. Like Attis he has sacrificed himself to the grand-mère, the Great Mother.

The Great Mother will not be without a son, however, and even before Bailey is shot the grandmother has found a new potential victim. " 'Bailey Boy,' the grandmother called in a tragic voice but she found she was looking at the Misfit squatting on the ground in front of her" (128). The grandmother says "Bailey" but looks at the Misfit—who is squatting just like Bailey was a minute ago (128)—because the Misfit is to be her new Bailey. But our study of the details of the latent relationship between Bailey Boy and the grandmother demonstrates that the Misfit is not Bailey. Indeed, we can discover a lot about both the Misfit himself and his climactic relationship with the grandmother just by contrasting details. Unlike Bailey who has "clattering teeth," (125) the Misfit has "a row of strong white teeth" (127). Unlike Bailey, the Misfit won't put up with the grandmother's fabrications: " 'We turned over twice!' said the grandmother. 'Once,' [the Misfit] corrected. 'We seen it happen' " (126). Unlike Bailey, the Misfit cuts the grandmother off: " 'Pray, pray,' the grandmother began, 'pray, pray . . . ' 'I never was a bad boy . . . ' " (130). And most importantly, unlike Bailey, the Misfit won't be mothered. The climactic scene is a most violent rejection of the grandmother as mamma and of the maternal breast.

> She saw the man's face twisted close to her own as if he were going to cry and she murmured, 'Why you're one of my babies. You're one of my own children.' She reached out and touched him on the shoulder. The Misfit sprang back as if a snake had bitten him and shot her three times through the chest. (132)

We could emphasize these contrasts to see "A Good Man Is Hard to Find" as a story of the ultimate defeat of the Great Mother. And since the Misfit sees the grandmother as a snake and picks up Pitty Sing after he kills the snake, we could see the story as the defeat of the Phallic Mother, the son's violent repossession of the phallus. And there is some validity to this view—but only some. The Misfit, for example, makes a correct association: the grandmother/snake has even "hissed" earlier in the story (121). But the snake is not just phallic, it also represents temptation. The Misfit suspects what the grandmother needs: a hard man is good to find. But his realization, "she would have been a good woman . . . if it had been someone there to shoot her every minute of her life," (133) is far too extreme. The Misfit accepts the phallus: he picks up the cat that has been rubbing against his leg (133). But the phallus has been neutered since Pitty Sing is now referred to as "it," not "he" (133). And the qualifications here emphasize just what we might expect from an author already renowned for manifest complexities: the latent story is not just a schematic presentation of the defeat of one son and the victory of another. It is not just a story of contrasts.

The Misfit is not simply "unlike Bailey." There is, in fact, some validity to the grandmother's feeling that the Misfit is the new Bailey. After all they do both squat, and squatting is feminine. The Misfit does put on Bailey's yellow shirt; he is scrawny like Bailey. And there's another particularly telling parallel between the two. Before Bailey goes to the woods and death he has one last moment of passivity, one last moment of talk without action.

> "Listen," Bailey began, "we're in a terrible predicament! Nobody realizes what this is," and his voice cracked. His eyes were as blue and intense as the parrots in his shirt and he remained perfectly still. (128)

Since voices have phallic connotations (Bunker 392), Bailey's cracking voice, like his immobility, reinforces his castration. But these reinforcements are particularly important later when the Misfit's voice changes: " 'Listen, [just what Bailey said] lady,' The Misfit said in a high voice, 'if I had of been there I would of known and I wouldn't be like I am now.' His voice seemed about to crack . . . " (132). The Misfit's voice is "about to crack," but it never actually does because he stops talking and starts shooting. The shooting of the grandmother, that is, is the Misfit's desperate attempt to shore up his tenuous and threatened masculinity. His voice almost cracks; he almost becomes Bailey: " 'Why you're one of my babies. You're one of my own children!' " (132). And almost is far too close for this man who is made nervous by children (126, 127) because he is nervous about still being a child. The Misfit will not be Bailey Boy; he will not be rendered puerile; he will not be smothered; he will not be caught in the Oedipal trap. Inept, insecure, and intimidated, he overcompensates with violence.

The Misfit's very assertion of maturity and independence manifests his immaturity and dependence. No one is more lost in Mother than Oedipus, and the Misfit resembles Oedipus. He has killed his father[1], and now with this phallic gun he attacks the mother. He fires three shots and after the attack his first concern is for his "red-rimmed" eyes (132). No wonder he sees the Great Mother as snake: she is the Oedipal temptation that cannot be avoided. Indeed, the intensity of the Misfit's aggression suggests the intensity of the temptation he's struggling to avoid. But even as he kills the temptress, at the latent level he succumbs to her. The grandmother smiles in death.

The Misfit is controlled just when he seems to take control, and this dilemma is reinforced by subtle details throughout the story. The sun and cloud imagery, for example, provides a perfect paradigm of the Misfit's plight. Before the Misfit comes on the scene, the children play their shape guessing game with a cloud "the shape of a cow," (120) and we are told twice that the sun is out (119, 122). Since we are also told that Bailey doesn't have "a naturally sunny disposition," (121) the latent implications here are not too subtle. The cloud which is the cow, the maternal principle, blocks off Bailey Boy, this most unnatural "sun." But when the Misfit arrives, he seems to rectify the situation. "Ain't a cloud in the sky . . . Don't see no sun but don't see no cloud neither" (127). The manifest improbability of this abrupt shift in the weather emphasizes the latent facts, which seem to be that, unlike Bailey, the Misfit is not lost behind the mother and that mother/sun imagery is not even relevant to the Misfit. These seem to be the facts—until we realize that the Misfit is not much of a meterologist.

A day that seems to be without sun or clouds really isn't. When the sun is not visible, it is being completely obscured by high level layered clouds, cirrostratus. It's no wonder that the grandmother responds to the Misfit's assertion that there is neither sun nor clouds with the seemingly incongruous " 'Yes, it's a beautiful day' " (127). It's beautiful for the Great Mother because this "son" doesn't even know he's lost in the clouds, lost in the maternal.[2]

And there appears to be little hope for the Misfit to escape the maternal since the Great Mother is as encompassing on earth as she is in the heavens. Since the Misfit has "plowed Mother Earth" (129) we might assume that, unlike Bailey who groans when the grandmother tricks him into going on a dirt road, (124) the Misfit has confronted and transcended the Maternal. But again this is not the case. The Misfit describes his later stay in prison in terms of the Maternal principle.

> "I never was a bad boy that I remember of . . . but somewheres along the line I done something wrong and got sent to the penitentiary. I was buried alive," and he looked up and held her attention to him by a steady stare. (130)

This bad boy Oedipus, killed his father and was "buried alive," lost in the maternal: The Earth Mother is his penitentiary. That his "escape" from the penitentiary only seems to distinguish him from Bailey who never escapes alive is emphasized in the last line here. The Misfit's staring at the grandmother immediately after he says "buried alive" emphasizes that the Earth Mother, the real penitentiary, is omnipresent.[3] The Misfit's stare holds her attention to him, but it's her "attention" that "holds" Bailey Boy, Pitty Sing, and the Misfit. That's why the Misfit still "plows" Mother Earth. "The Misfit pointed the toe of his shoe into the ground and made a little hole and then covered it up again . . . the Misfit . . . drew a little circle in the ground with the butt of his gun . . . the Misfit kept scratching in the ground with the butt of his gun" (127, 128, 129). Like the shooting of the grandmother, the union of toe or gun and Mother Earth—the union both dirty and obsessive—is the symbolic rendering of the repressed Oedipal union that the Misfit both dreads and desires.

The union of gun and ground is, however, more than the sublimated fulfillment of repressed desires. The Misfit is struggling to find—struggling to free—his own self that is still buried alive. And "struggling" is the key word. This is what makes the Misfit unlike Bailey. The Misfit struggles; Bailey gives up. It's a case of "approach-avoidance": the Misfit approaches; Bailey avoids. The Misfit, as his daddy said, is one of those " 'that has to know why,' " (129) and from his first appearance in the story he is struggling to see so that he can comprehend.

> In a few minutes the family saw a car some distance away on top of a hill, coming slowly as if the occupants were watching them . . . It came to a stop just over them and for some minutes, the driver looked down with a steady expressionless gaze to where they were sitting . . . The driver got out of the car and stood by the side of it, looking down at them. (125, 126)

The Misfit's gaze, which will soon be focused solely on the grandmother, distinguishes him from Bailey, who is also characterized by his initial visual response to the grandmother—her hip, her newspaper, and her efforts to go to Tennessee: "Bailey didn't look up from his reading" (117). Bailey, that is, avoids dirt, cat, *and* grandmother: he fears the filth of his phallic Oedipal desires. The Misfit approaches dirt, cat, and grandmother: he is not afraid to discover his "dirty" self. And if he doesn't understand what he sees, he at least looks; if he overreacts, he at least reacts; if his voice almost cracks, he at least stops talking; if his masculinity is threatened, he at least cares. And if he repeats, symbolically, his unconscious Oedipal longings, at least he repeats those longings. Bailey does not. Bailey's longings are so repressed that he never even enacts symbolic sexual union. The Misfit has a better chance to find himself in, and free himself from, the Earth Mother because his desires which he must come to "know" are closer to the surface, and his symbolic confrontations provide him opportunities to understand. If he succumbs to the temptress, at least he has a chance to understand the nature of the temptation. Indeed, it seems that the violent intensity of the Misfit's killing/possessing of the Great Mother thrusts him forward towards knowledge and freedom. He at least has removed the blocking figure. When the grandmother is dead the weather changes again. Now there is merely a "cloudless sky" (132).

The cloudless sky emphasizes that the blocking mother is gone and suggests that it is no longer necessary to talk of "sun." The Misfit, who first moved from looking at grandmother to "looking beyond her," (132) has now moved from confronting Mother to transcending her. After the shooting he immediately "[puts] his gun down on the ground and takes off his glasses and begins to clean them" (132). Now he will be able to see beyond the dirt of the obsessions he has just confronted. He knows instinctively that he will no longer need the gun for shooting or digging: the mother has been encountered, possessed, and purged; the Misfit has plowed Mother Earth and he no longer needs to look for himself in the dirt. He is free. He no longer needs to assert his masculinity. "Without his glasses, the Misfit's eyes were red-rimmed and pale and defenseless-looking" (132, 133). He is, then, not only beyond the violent masculinity implicit in his gun, he is beyond gender. He picks up "the cat that is rubbing itself against his leg" (133). And it is now "the cat" not "Pitty Sing", "itself", not "himself" because now the phallus is neither feminized nor masculinized. Like the only androgyne in O'Connor's work, the cat is "it."[4] Beyond mother, beyond Oedipal violence, beyond gender, the Misfit has come to knowledge. Bobby Lee, tugging the grandmother out of the ditch to throw her with Bailey, yells "some fun," (133) but the final word is the Misfit's "shut up, Bobby Lee, it's no real pleasure in life" (133). The Misfit has come a long way from "No pleasure but meanness" (132). He has come a long way from the Oedipal "pleasures" that Bobby Lee still "wrestles" with, a long way from the ditch that he wrestles in. The Misfit, because he approaches, ends up with knowledge. Bailey Boy, because he avoids, ends up with Grandmother.

We, in turn, end up with an understanding of the story's depths because we began with "The Tennessee Waltz;" we began by considering subtle details. And this is how all of O'Connor's work must be read. Throughout her fiction, apparently inconsequential details reveal themselves under the scrutiny of a Freudian frame of reference. And it is these revelations that lead to ultimate understanding. Still, even a listing of details that could lead us into other O'Connor stories would be quite lengthy. But all of O'Connor's work forms an intricate whole: she herself says, "In the future, anybody who writes anything about me is going to have to read everything I have written in order to make legitimate criticism" (*Being* 450). O'Connor's stories reinforce and refine each other. So the process of finding and explicating details is not as formidable as it might seem since many pivotal details are recurrent, and their latent associations are being continually refined and reinforced. Consider a few examples of how our understanding of "A Good Man Is Hard to Find" can suggest places to penetrate other stories by shedding light on details that might initially seem inconsequential or incomprehensible. In "Comforts of Home" Thomas thrusts his gun into Sarah Ham's purse, and since we've seen that guns are, among other things, phallic, we should suspect that Thomas' action has latent implications. Indeed, once we know where to look, the latent implications are almost transparent since the details reinforce the symbol. "He grabbed the red pocketbook. It had a skin-like feel to his touch and as it opened, he caught an unmistakable odor of the girl. Wincing, he thrust in the gun and then drew back" (402). When Thomas' mother "[collapses] full-length on his couch lifting her small swollen feet upon the arm of it" (387) we see how the swollen feet, which takes us to Oedipus (Jobes 2: 931), help us with the scene because we know how O'Connor uses Oedipal concerns and subtle allusions. When Thomas, bareheaded, talks to the imposing Farebrother with his "Texas type hat," (400) Thomas uses a "lamer voice" (400) and we know what's going on because we've seen some of the association of hats, limps, and voices.

This, too, is typical O'Connor: the images we have learned to deal with in "A Good Man Is Hard to Find" reinforce each other throughout O'Connor's work. In "A Circle in the Fire," for example, guns and hats help us understand Sally Virginia's attempt to become the dangerous phallic male. "[She] had put on a pair of overalls over her dress and had pulled a man's old felt hat down as far as it would go on her head and was arming herself with two pistols" (190). In "The Partridge Festival" guns and hats expose Singleton's phallic nature right before Singleton exposes his phallus. "On his head was a black hat, not the kind countrymen wear, but a black derby hat such as might be worn by a gunman in the movies" (442). In "Greenleaf" guns and hats along with suns and our awareness of the mother and son's struggle for the phallus help us with a more complex passage. "[Mrs. May] was conscious that the sun was directly on top of her head, like a silver bullet ready to drop into her brain" (325). Mrs. May is hatless so her unprotected head is most vulnerable to the phallic shaped sun—the son's gun. But when the mother wears a hat as LucyNell Crater does in "The Life You Save May Be Your Own" things are different.

> She was about the size of a cedar fence post and she had a man's gray hat pulled down low over her head . . . The old woman watched him with her arms folded across her chest as if she were the owner of the sun. (146)

This hatted post, this phallic mother is most assuredly the "owner" of this one-armed son. Pitted against this devouring mother, "ravenous for a son-in-law," (150) it is Mr. Shiftlet "deeply hurt by the word milk" (153) who is vulnerable. Our images demonstrate that Shiftlet's attempts to avoid and suppress mother are—as we might expect—futile. After Shiflet has taken LucyNell Crater's car and abandoned her daughter.

> A cloud, the exact color of the boy's hat and shaped like a turnip, had descended over the sun, and another, worse looking, crouched behind the car. Mr. Shiftlet felt that the rottenness of the world was about to engulf him. (156)

Since we've seen that clouds can be maternal, we might be surprised that Shiflet links this cloud with a boy's hat. But we must recall that the boy's hat is gray (155) just like Mrs. Crater's hat. So the engulfing gray turnip shaped cloud is really the Earth Mother, the phallic mother, and Shiftlet's focus on the boy's hat demonstrates his own desires to repress the mother and retrieve the phallus. However, these desires are ineffectual; the "sun" is lost; Shiftlet, who has repeatedly fed the Crater women because he has always feared that he himself might be their next meal, is engulfed. And not only does our study of "A Good Man Is Hard to Find" help us with his defeat, the oral nature of his defeat helps us with "A Good Man Is Hard to Find." The devouring mother in "The Life You Save May Be Your Own" points us toward the devouring mother—the oral precursor of the Oedipal phallic mother—in "A Good Man Is Hard to Find." Now we can understand certain details in this story. We can see why Bailey, with his "clattering teeth" (125) makes sure that the grandmother gets two lunches, one on the road and one at Red Sammy's. And we can see why the Misfit with his "strong white teeth" (127) shoots the grandmother in the chest when she bites him.

The process, of course, is endless. Latent obsessions reinforce and refine each other; stories reinforce and refine each other; image clusters reinforce and refine each other in a particular story and throughout the O'Connor canon. It's all quite complicated, but it all began with "The Tennessee Waltz." And we should learn from Bailey: "ya dance with who brung ya." Careful consideration of manifest details takes us into and through O'Connor's maze of latent complexities.

Endnotes

[1] The illogic of the Misfit's denial of this murder suggests that he has suppressed his patricide. "It was a head doctor at the penitentiary said what I had done was kill my daddy but I know that for a lie. My daddy died in nineteen ought nineteen of the epidemic flu and I never had a thing to do with it. He was buried in the Mount Hopewell Baptist churchyard and you can go there and see for yourself" (130). That the tombstone reads, "died of the epidemic flu" is almost as unlikely as it reading "19019." In any case Eggenschwiler has demonstrated that is makes little difference whether the Misfit's patricide is actual or symbolic. (143)

[2] It's interesting to note here that even the only possible manifest "excuse" for the Misfit's error actually reinforces the latent point. Perhaps the Misfit is too deep in the ditch to view the sun and clouds—well perhaps, but he's either lost in the clouds or lost in the "red gutted ditch" (125).

[3] The grandmother is most assuredly the Earth Mother. The first earth we see is the "blue granite . . . the brilliant red clay banks slightly streaked with purple; and the various crops that made rows of green lacework on the ground" (119). The grandmother has the blue, her blue hat and dress (118); the red, her red face (124); the purple, her purple spray of violets (118); and even the lace, her lace trimmed collar and cuffs (110). She is just like the earth—except for the green. She offers neither Bailey Boy nor the Misfit fertility. The children's mother, on the other hand, never takes off her "green headkerchief that [has] two points on the top like a rabbit's ears" (117).

[4] The androgynous "freak" in "A Temple of the Holy Ghost" is referred to as "it" (245).

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Population Ecology of Painted and Blanding's Turtles (*Chrysemys picta* and *Emydoidea blandingi*) in Central Wisconsin

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Abstract. *A Blanding's turtle* (Emydoidea blandingi) *population was studied for six years in central Wisconsin. To date, five studies of Blanding's turtle populations have appeared in the literature. Females matured at 172-mm plastron length and at about 18 years of age. Size and age at maturity in males remains unknown. Density and biomass were 27.5 turtles/ha and 45 kg/ha; these densities are greater than those found in Michigan marshes but less than densities reported for Missouri pond populations. Biomass was greater than that found in Michigan marshes. As in three other studies, no small juveniles were captured. Similar to two other studies, growth rate was greatest early in life and steadily declined thereafter. The Wisconsin population exhibited faster growth than that reported for Ontario and Massachusetts populations. The rapid growth rate, especially in the first several years of life, is probably related to organic substrates in the wetlands and associated high productivity of animal food items. Individuals were recaptured frequently and often moved among several adjacent wetlands. Habitat for* E. blandingi *should be set aside to preserve populations of this species.*

Male and female painted turtles (Chrysemys picta), *studied simultaneously with* E. blandingi, *matured at about 85-mm and 130-mm plastron lengths, respectively. This is similar to that found in southern Minnesota, but both sexes mature at larger sizes than those in southern Michigan. Density of the* C. picta *population was 104 turtles/ha, less than that found in other studies. Ages at maturity were three and seven years for males and females, respectively. Males matured at an earlier age than those in southern Michigan and at the same age as those in New Mexico and Illinois. Females matured at the same age as most other upper Midwest populations. Growth rate was rapid during the first several years of life, similar to other Midwest populations. Interspecific competition for food and basking sites may exist between* E. blandingi *and* C. picta.

Data are available from several studies on the population dynamics of Blanding's turtle (*Emydoidea blandingi*) (Gibbons 1968a; Graham and Doyle 1977; Congdon et al. 1983). The State of Wisconsin lists *E. blandingi* as threatened (NR 27.03, effective October 1979). Only one study (Ross and Anderson in press) has been conducted on Blanding's turtle in Wisconsin. That study examined habitat use and movements in the present population. Painted turtle (*Chrysemys picta*) ecology has been studied in Wisconsin (Pearse 1923; Ream and Ream 1966) and other parts of midwestern North America (Cagle 1942, 1954; Sexton 1959b; Gibbons 1968; Ernst and Ernst 1972; Wilbur 1975;

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MacCulloch and Secoy 1983). The objectives of this study were to examine size class distribution, size/age at maturity, population density, and biomass (*E. blandingi* only) of sympatric populations of painted and Blanding's turtles in Wisconsin.

Study Area and Methods

The study was conducted on the Petenwell Wildlife Area (PWA), a 291 ha wetland complex located in the Town of Strongs Prairie, Adams County, Wisconsin (T18N, R4E). The PWA wetlands consist of small (<0.2 ha) ponds, marshes, creeks, ditches, alder swamps, and oak (*Quercus* spp.) and aspen (*Populus* spp.) woods. Dominant emergent vegetation includes cattail (*Typha* spp.), sedge, and bulrush (*Juncus* sp.). Dominant submergent vegetation includes coontail (*Ceratophyllum demersum*), elodea (*Elodea canadensis*), and pondweeds (*Potamogeton* spp.). The PWA is located in the flat, sandy glacial outwash plain of central Wisconsin (Martin 1965).

Turtles were trapped in ponds (hereafter, pond complex), with hoop nets (Legler 1960) during June to September 1985, and May to July 1986, for a total of 1,290 trap nights. Recapture data of turtles marked during 1982 and 1983 (Ross and Anderson in press) were used in some of the present analyses. Traps were baited with frozen fish that were renewed daily. The surface area of the pond complex was 0.8 ha. Occasionally, individuals were captured by hand, mainly nesting females on land. All turtles were individually marked by notching marginal scutes with a hacksaw (Cagle 1939). *Emydoidea blandingi* were classified as male if a concave plastron was present and as female if the plastron was flat (Graham and Doyle 1977). *Chrysemys picta* were classified as male if elongated claws were present on the front feet and as female if the individual was larger than the largest mature male and lacked male secondary sex characters. Turtles less than the smallest mature male were classified as immatures. X-ray photography (Gibbons and Greene 1979) and specimen dissection (Tinkle 1961) are accurate methods for determining the age of turtles at sexual maturation. However, inspection of secondary sexual characters (i.e., females are classified as those individuals lacking male sex characters greater than the smallest known male) were the best methods available for this study. Shell measurements were taken with calipers, and body weights were obtained with spring scales. Plastral growth annuli, when distinguishable, were measured with dial calipers and were used to age turtles (Sexton 1959a). The relative lengths of the abdominal laminae and the plastron remain about the same throughout the life in *Emydoidea* (Graham 1979). Previous annual growth was estimated by applying the equation $L_1/L_2 = C_1/C_2$ where C_1 represents the length of the annulus, C_2 the length of the abdominal scute, L_2 the plastron length (PL), and L_1 the length of the plastron at the time the annulus was formed (Sergeev 1937). Population size was calculated according to the Schnabel method (Schnabel 1938) using Chapman and Overton's (1966) method of calculating confidence limits (CL). Biomass was estimated as the sum of the weights of all *E. blandingi* captured in the pond complex during 1985 and 1986. Daily air temperatures were obtained from the Necedah Weather Station, about 6 km west of the PWA.

Results and Discussion

A total of 32 *E. blandingi* were trapped in the pond complex (Fig. 1). Twenty-three (72%) turtles were recaptures from previous years of study (1982 and 1983) (Ross and Anderson in press). Of the total Blanding's turtles, 9 (28%) were males and 23 (72%) were females. Of these, there were 4 immature females and 1 possibly immature male. The sex ratio was 1 (male): 2.5 (female) and significantly different from 1:1 ($P<0.05$, $X^2 = 6.2$). However, the relatively small sample size and statements by Ream and Ream (1966) and Gibbons (1970) question the validity of sex ratios differing from 1:1. Of the total adult painted turtles, 72 (58%) were

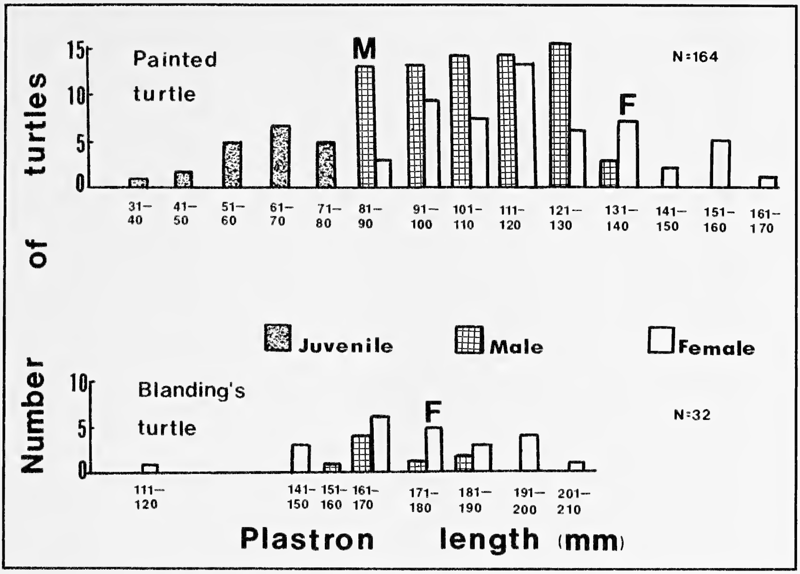

Fig. 1. Size classes of Blanding's and painted turtles. M and F indicate size at maturation in males and females, respectively.

males, and 53 (42%) were females. The sex ratio is not significantly different from 1:1 ($P>0.05$, $X^2 = 2.8$). This is similar to that found in other studies (Table 1). Immatures represented about 35% of the population (Fig. 1); the immature to adult ratio was 1.8:1. Age ratios in *C. picta* vary widely among studies (Table 1). Such variation is due to sampling design and a variety of other factors (e.g., predation, longevity, and habitat quality).

No *E. blandingi* smaller than 111 mm PL were captured. Gibbons (1968) and Graham and Doyle (1977) all noted an apparent scarcity of juvenile Blanding's turtles. Congdon et al. (1983) believe that considering probable high mortality and predation of eggs and hatchlings, a true scarcity of younger age classes exists. However, on 25 May and 9 June 1987, two road-killed *E. blandingi* (65 mm PL and 114 mm PL, respectively) were collected near shallow (<0.5m) marshes adjacent to the PWA. Perhaps juveniles use habitats separate from adults, thus rendering them less vulnerable to sampling techniques employed in this study.

The Blanding's turtle population in the pond complex was estimated at 21 individuals (CL = 15–29), providing a density estimate of 27.5 Blanding's turtles/ha. Blanding's turtles occur at lower densities in marshes in southern Michigan (8.8 and 10.0 turtles/ha) (Congdon et al. 1986), while a pond in Missouri held densities of 55 turtles/ha (Kofron and Schreiber 1985) (Table 2). These density estimates are low in comparison to those of other freshwater turtle populations (Iverson 1982). Painted turtles attained an estimated density of 104 turtles/ha in the pond complex, lower than that of other similar studies (Iverson 1982). The biomass estimate for the Blanding's turtle population in the pond complex is 45 kg/ha. Biomass estimates for two Michigan marshes (Congdon et al. 1986) were

Table 1. A comparison of age compositions in painted turtles (*Chrysemys picta*)

Locality	Immatures Total	Immatures %	Adults Total	Adults %	Ratio Juv. = 1	Reference
Saskatchewan	27	18	125	82	4.56	MacCulloch and Secoy 1983
Illinois	98	41	139	59	1.41	Cagle 1942
Illinois	124	51	120	49	0.97	Cagle 1954
Pennsylvania	180	19	374	81	2.08	Ernst 1971b
Minnesota	17	24	54	76	3.18	Ernst and Ernst 1972
Michigan	141	58	102	42	0.72	Cagle 1954
Michigan	305	39	480	61	1.57	Gibbons 1968
Wisconsin	51	10	479	90	9.39	Ream and Ream 1966
Wisconsin	58	35	106	65	1.83	This study
					$\bar{x}$ = 2.86	
					SD = 2.721	

Table 2. A comparison of estimated densities in Blanding's turtle (*Emydoidea blandingi*) populations

Locality	Habitat	Density no./ha	Source
Massachusetts	Marsh	6.3[a]	Graham and Doyle 1977
Michigan	Marsh	8.8	Congdon et al. 1986
Michigan	Marsh	10.0	Congdon et al. 1986
Michigan	Marsh	15.8[a]	Gibbons 1968
Missouri	Pond	55.0[a]	Kofron and Schreiber 1985
Wisconsin	Pond	27.5	This study
		$\bar{x}$ = 20.6	
		SD = 16.88	

[a]Extrapolated data.

7.9 kg/ha and 8.8 kg/ha, respectively. The differences between the two localities may be a reflection of the concentrated habitats found in the present study (there is little similar habitat nearby), as well as the apparent abundance of aquatic prey. Aquatic macroinvertebrates (e.g., *Odonata* sp., leeches, and snails), small fish, and frogs are common in the pond complex. Iverson (1982) states that populations within ponds tend to have higher biomasses than those in marsh habitats. Biomass in reptiles and amphibians often exceeds that of sympatric higher vertebrates (Burton and Likens 1975; Fitch 1975; Iverson 1982; Reichenbach and Dalrymple 1986) that receive greater management attention. Conservation agencies should give more consideration to reptiles and amphibians because, ecologically, they are equally as important as more highly managed (i.e. game) species.

Female *E. blandingi* reached sexual maturity at about 172 mm PL as all gravid females with visible annuli captured were greater than or equal to this length ($\bar{x}$ = 191.4, range 172–215 mm PL). Age at sexual maturity in males remains unknown. All females greater than 172 mm had at least 18 visible annuli. This indicates that maturity, in Wisconsin individuals, may be related to size rather than age, the opposite for *Emydoidea* in Massachusetts (Graham and Doyle 1977). This characteristic has been noted in other species of turtles as well (Bury 1979). Blanding's turtles in Michigan mature at about 162 mm PL, the age at maturity remaining unknown (Congdon et al. 1983). The largest *Emydoi-*

dea in this study was a 215 mm PL female.

Sexual maturity was attained in *C. picta* at 80–85 mm PL and 130 mm PL in males and females, respectively. All gravid females captured were between 130 mm and 158 mm PL, similar to measurements of gravid females found in other midwestern populations (Gibbons 1968; Christiansen and Moll 1973; Tinkle et al. 1981). Females and males reached sexual maturity at about seven and three years of age, respectively, similar to findings by Ernst and Ernst (1972) and Christiansen and Moll (1973). Gibbons (1968) and Tinkle et al. (1981) found that females and males mature at about seven and five years of age in southern Michigan. Cunningham (1922) found that males and females mature at 88 mm and 130 mm, respectively, in Wisconsin. Males and females matured at 90 mm PL and 112 mm PL, respectively, in southern Michigan (Tinkle et al. 1981). Southwestern Minnesota *C. p. belli* display variable growth rates after the first season, with the growth rate declining as turtles increase in size. Maturity in males is reached at a PL of about 95 mm in the third or fourth year. Females mature at about 110 mm PL and in their fourth or fifth year (Ernst and Ernst 1972). Male *Chrysemys* typically reached maturity before females (Fig. 1). The largest *Chrysemys* captured in the PWA was a 168 mm PL female.

Percent growth in *Emydoidea* was greatest during the first year of life (85.9%), and thereafter growth steadily declined until year 8 (Table 3), after which many annuli were indiscernible. These growth rate data correspond with Graham and Doyle's (1977) data, except that growth in their Massachusetts population was slightly less (81.4%) during the first year of life. Two Blanding's turtle populations in Ontario grew at an even slower rate in the first year (65.5% and 58.5%) (Petokas 1986) than did PWA turtles. The growth rate during the following seven years in the Ontario populations was also less than that of the PWA population. This should be accepted with caution because Petokas (1986) aged *E. blandingi* that were greater than 11 years of age, which was not possible in the present study due to excessive plastral wear. Prey abundance may be greater in PWA habitats, thus increasing the growth rate in the population (Graham and Doyle 1977). Turtles inhabiting wetlands with organic substrates display more rapid growth than turtles from sand-bottomed (low organic) wetlands (Quinn and Christiansen 1972; Moll 1976). The pond complex has an organic substrate while Petokas's (1986) population inhabited wetlands with sand substrate. This phenomenon is probably related to the relatively high productivity of animal prey in organic substrates versus that of wetlands with sand substrate, resulting in faster growth rates (Gibbons 1967; Moll 1976; Quinn and Christiansen 1972). MacCulloch and Secoy (1983) sug-

Table 3. Estimated plastral growth of nine *Emydoidea blandingi* from the Petenwell Wildlife Area, 1986–1988. N refers to the number of individuals.

Year Class	N	Plastron Length (mm) $\bar{x}$	Range	SD	Mean Annual Increment (mm)	% Growth
Hatchling	8	29.7	22.3– 35.3	4.75	–	–
1	8	55.2	47.0– 62.3	5.50	25.5	85.9
2	9	73.7	54.7–105.1	5.10	18.5	33.5
3	7	91.7	65.3–131.9	23.59	18.0	24.4
4	7	102.2	75.4–142.9	25.04	10.5	11.5
5	7	114.4	86.6–155.9	27.33	12.2	11.9
6	6	115.3	94.4–157.9	24.04	0.9	0.8
7	6	122.8	104.5–172.8	26.44	7.5	6.5
8	4	143.6	125.1–185.8	28.58	20.8	16.9
9	2	133.4	132.1–134.7	1.84	0.0	0.0
10	1	136.3	–	–	2.9	2.2
11	1	142.2	–	–	5.9	4.3

gested that the large body size and rapid growth rate observed in *C. p. belli* from Saskatchewan is probably due to a carnivorous diet.

Growth rate in *C. picta* was rapid during the first year of life (95.7%) and declined rapidly thereafter (Table 4). This growth rate is similar to that found by Ernst (1971a), Ernst and Ernst (1973), and Hart (1982). Attainment of maturity caused growth rate to slow even further (Table 4) as found in other midwestern studies (Ernst and Ernst 1972; MacCulloch and Secoy 1983).

Certain areas of the pond complex appeared to hold concentrations of *C. picta*. This was probably due to the availability of basking sites, food, or mating behavior (Vogt 1979). *Chrysemys* basked as early as 28 February due to sunny skies and air temperatures of 19°C. Vogt (1981) observed painted turtles active under the ice during early March in Lake Mendota, Wisconsin. Ernst (1971b) also observed painted turtles active as early as March in Pennsylvania.

During this study, many *E. blandingi* were recaptured. Time intervals spanning recapture varied from one day to four years; the length of time separating trapping dates may have affected these results. Increased trapping efforts during other seasons would probably have lessened the time span between recaptures. Movements were common among the wetland complex as shown in the trapping data. Blanding's turtles (N = 17) moved relatively long distances within the wetland complex ($\bar{x}$ = 396.2 m, SD = 114.47 m, Range 212–652 m). Fifteen other *Emydoidea* were considered "residents" of the pond complex as they were only captured within that complex. Congdon et al. (1983), working in Michigan, found that many individuals were "residents" of a particular area. Of 30 turtles recaptured within the pond complex or nearby (<600 m) wetlands, 27 (90%) turtles were trapped in that complex at least twice during the present study, indicating a resident population.

Most of the *C. picta* population on the PWA consists of subadults and young adults (Fig. 1), indicating a stable, growing population. Additionally, recaptures of many individuals indicates a well-defined sedentary population. The immature adult ratio is greater than that in other similar studies (Table 1). There also appears to be little difference in age at maturity of *C. picta* populations in the PWA as compared with that of other upper Midwest populations. Growth rate of PWA *C. picta* is rapid early in life (Table 4), similar to that found in other studies.

Low-density freshwater turtle populations may be related to a scarcity of basking sites (Pritchard and Greenwood 1968; Harless 1979). *Chrysemys* populations attaining higher densities are found in shallower habitats (Gibbons 1968b; Ernst 1971b) than those in the present study; maximum depth in PWA habitats is 0.7 m—1.3 m. *Chrysemys* and *Emydoidea* may be competing for food and basking sites. In Wisconsin, *C. picta* and *E. blandingi* feed on similar prey (Vogt 1981).

Table 4. Estimated plastral growth of 53 *Chrysemys picta* from the Petenwell Wildlife Area, 1985–1988. N refers to the number of individuals.

Year Class	N	Plastron Length (mm) $\bar{x}$	Range	SD	Mean Annual Increment (mm)	% Growth
Hatchling	30	25.7	20.5– 39.4	4.75	–	–
1	35	50.3	37.0– 59.4	7.37	24.6	95.7
2	28	65.1	54.1– 94.5	8.90	14.8	29.4
3	17	79.4	66.1–111.2	9.88	14.3	21.9
4	18	88.4	73.0–116.0	10.86	9.0	11.3
5	9	102.5	81.0–124.1	12.57	14.1	16.0
6	7	115.0	92.0–135.4	16.51	12.5	12.2
7	4	131.7	119.8–137.0	9.06	16.7	14.5
8	1	127.0	–	–	–	–

However, *E. blandingi* attains a greater size than *C. picta* (Fig. 1), allowing speculation that *E. blandingi* feeds on larger prey than does *C. picta*. Within the PWA, few basking sites exist disjunct from shore; both species frequently bask in close proximity to one another during April and May. The turtles may not be using the best available basking sites as 26% of the *C. picta* population was depredated apparently while basking in April, 1987 (Ross 1988). Spring predation of immatures and adults may be a factor in limiting the *C. picta* population in the PWA. Similarly, both species reach their greatest densities in pond habitats. (*E. blandingi,* Table 2; *C. picta,* Bury 1979; Iverson 1982). *Chrysemys* males exhibit higher rates of growth in pond habitats than in river habitats (Gibbons 1967). Petokas (1986) speculated that in one high-density Ontario population of *E. blandingi,* intraspecific competition for food resources was present.

Competition between sympatric species often limits the population size or growth rate of either or both species. Despite apparent basking sites and, perhaps, food competition, *E. blandingi* and *C. picta* in this study attain larger body sizes than several studies of the respective species in southern Michigan. Growth rate early in life in PWA *E. blandingi* and *C. picta* is rapid. These characters are probably positively correlated with the wetland productivity in the PWA. Habitat quality in relation to population characteristics should be studied in other reptiles to provide baseline data for future protection and management guidelines.

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Racism and Its Limits: Common Whites and Blacks in Antebellum North Carolina

Bill Cecil-Fronsman

In 1802 the "Incorporated Mechanical Society of Wilmington" petitioned the North Carolina General Assembly to tighten up enforcement of the laws prohibiting slaves from hiring their own time. According to the petition, slaves were working for less than half the rate a white mechanic charged and were hiring apprentices who, with their employers, were free to consort and plot insurrections. The petition concluded that because the white mechanics served on juries, performed military duties, and paid taxes, it was unfair that "bread should be taken out of the mouths of themselves and families by persons, who circumstanced as they are, are the irreconcilable enemies of the Whites." [1]

In 1809 John P. Waters of Wilkes County, a county located on the western edge of the piedmont, drafted a petition asking that the State Legislature relieve him of a large fine. It seems that Waters had fallen in love with Elisabeth Culms, "a woman of colour," and had begun living with her. The petition stated that he knew this was wrong and that he wanted to marry her, but he knew that such a marriage was illegal. "In the mean while," he wrote, "an Intimacy took place which appeared Irresistable, the fruits of which has been six fine children." John and Elizabeth were convicted and fined twenty-five pounds each, a sum greater than the value of all he possessed. Although he knew that living with her was "unlawful and Irreligious," he refused to abandon his family. "He is from the love he bares his said little children and their kind mother, still desirous to keep them together to do a fatherly & Husbands part by them, as time or circumstance cannot alienate them from him." [2]

These two petitions, written only seven years apart, in the same state, by men of comparable status, demonstrate the range of common-white beliefs about race. Common whites were white nonslaveholders and small slaveholders who were perceived by themselves and others as not being members of the society's political, social, or economic elite. It is admittedly more difficult to determine who was not a common white than who was. An individual owning twenty slaves certainly would not have been a common white. Most individuals owning no slaves would have been, although some nonslaveholders were quite wealthy or politically and socially prominent. In North Carolina, where this study is focused, 70.8 percent of the whites owned no slaves in 1860. Of the nearly 35,000 slaveholders only around 9,100, or approximately 7.7 percent of the total population, owned as many as ten. For the purpose at hand one may assume that roughly eighty to eighty-five percent of North Carolina's white population was "common." [3]

It is a widely held assumption among historians that the common whites were extraordinarily racist and that their racism cemented their loyalties to the slaveholders' regime. This racism further led them to plunge themselves into a blood bath to preserve slavery in 1861. The standard accounts of the roles of common whites in the political crisis of the 1850s all emphasize this point. "The importance of the racial issue cannot be overemphasized," writes William L. Barney. "Racism was the secessionists' greatest weapon. They knew precisely what Southerners dreaded most and by constantly exacerbating this fear . . . [they] succeeded in

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building up tensions and hatreds which looked to secession as an outlet." The racism of the common whites was, in the words of William J. Cooper "omnipotent" and led them to have "no interest in challenging the social order guaranteed by the slave system, which provided social peace despite the presence of millions of blacks, a group white yeomen believed absolutely inferior." [4]

Historians who have grappled with the problems of common-white racism have recognized that this racism took a different form than the paternalism that some historians have ascribed to the planter class. Eugene D. Genovese argues that a sense of responsibility to the alleged inferiors on the plantation evolved among the slaveholding class. This argument, however, has little bearing on the individuals who did not own any slaves. Instead, most scholars have ascribed to the common whites a harsher racism, born out of a fear of competition. Steven Hahn writes how yeoman farmers viewed blacks as "symbols of a condition they most feared—abject and perpetual dependency." The slaves' strict subordination "provided essential safeguards for their [yeomanry's] way of life." As petty property owners, they sought to define "the dispossed out of the political community." [5]

For some commentators, common-white racism is chiefly defined by its competitive quality. Pierre L. van den Berghe's comparative study of race relations sets out two broad types of biracial societies. The first is the paternalistic type, in which wide gulfs in status, occupation, and income separate racial castes. The second, or the competitive type, is an arrangement in which a color bar exists, but the existence of that color bar does not prevent members of the subordinate race from approaching members of the dominant race. The result is often competition. In the paternalistic type, all persons know their places, and the dominant group needs relatively little violence to ensure its position. In the competitive type, roles are ill-defined and violence serves to enforce the dominant race's position. In these regimes a kind of *herrenvolk* democracy emerges, in which egalitarian ideals may flourish but are restricted to the dominant race. George M. Fredrickson has developed this perspective by contending that the southern elite class used the rhetoric of *herrenvolk* democracy to protect their positions from potential assaults from within the region and from real assaults from the North.[6]

The thesis of this essay is that these characterizations of common whites must be qualified. No one who has studied antebellum southern whites can deny their racism or deny that it played an important role in ensuring that they would take steps to protect slavery. But a close examination of the records they left behind suggests that there were limits to their racism. Some common whites rejected and others significantly modified the racism that was so pervasive. They set limits to their racism because they found that such limits met their personal needs for intimacy and friendship or because they found an "omnipotent" racism to be incompatible with their conflicts with the planter class.

For the purpose at hand, racism will be defined as the collection of norms that prescribe strict boundaries between the social space of whites and that of blacks. It is a cultural phenomenon that requires barriers separating blacks and whites. These barriers might include the way people act in public, the kinds of jobs they can hold, the sorts of people they can love, or with whom they can engage in sexual relations. Racist norms assert that the barriers are not only legitimate, but that steps must be taken to strengthen and maintain them.[7]

If one accepts the notion that racism is a phenomenon that designates strict barriers between whites and blacks, then certain racist actions start to make sense. For example, in 1818 an Iredell County militia company requested a law to prevent blacks from loitering while the company drilled. Although Iredell County was less than one-quarter black, the men complained about "the Numirous quantity of Negroes which generally assemble at Regimental or batalion Musters . . . which is productive of much vice & immorality." [8] By taking this action, common whites helped to widen the gulf between themselves and blacks by asserting that some kinds of activities were simply not appropriate for so degraded a caste. White observers, in contrast, were obviously not members of an inferior caste because their presence was welcome.

A second sentiment which these Iredell County petitioners asserted was that the black presence led to vice and immorality. This implied not only a generalized aversion towards blacks but also imputed to them a particular, inevitable quality. This projection helped ensure that the boundaries between the races would remain fixed. Common whites could define themselves in contrast to blacks: "they are given to vice and immorality; we are not." Common whites thus appropriated a certain status for themselves by assigning the opposite one to blacks.

Among the many characteristics which common whites projected onto blacks was that of thievery. In 1848 when James G. Mitchell of Raleigh asked for permission to erect a shanty on a state rock quarry, he offhandedly noted that it might protect the quarry from "negro and other plunderers." [9] There was a basic acceptance of this belief. Common whites humorously referred to the alleged "negro trait" in this popular folk ditty:

Some folks say a nigger won't steal
But I caught seven in my corn field
One had a bushel and the other had peck
One had a roas'n ear strung around his neck.[10]

By conceiving of black people as thieves the common whites thus defined themselves as something else and hence worthy of admiration.

Not only did common whites differentiate themselves from blacks by conceiving of them as transgressors of the law, as shown by the folk ditty and the example of the Wilmington mechanics cited in the introduction, they also used their beliefs about black sexuality to set themselves apart. A joke from eastern North Carolina illustrates a widely held common-white assumption about black men. A planter had a slave, Sam, whom he used for breeding. A friend of the planter's asked to borrow him for the women on his own plantation. The owner left the decision up to Sam. The slave was reluctant; his owner encouraged him, saying there were some "nice black gals waiting there." —"How many?" —"five or six" —"Boss, if it jes' as well wid you, I druther not go. Too far a piece fer jes' a half-day's work."[11]

In 1802 there was an insurrection scare in the northeastern part of the state. The anxieties expressed suggest something of what lay behind the fears of common whites and their planter neighbors. According to the reports of this alleged conspiracy, the rebels planned to burn the town of Windsor. They were then to kill all the white men and older black women. After accomplishing this deed they would keep the white women for themselves while using the black girls as servants. From then on, the reports claim, "they were to have their freedom and live as white people." [12]

Common-white men believed that possessing white women was one of the symbols that set them apart from black men. When they imagined blacks on a rampage, it was natural that they believed the slaves would seek to capture the whites' own prized possessions. In order to have freedom and live as white men, blacks would need white women. By denying blacks access to their women, whites believed they were denying something that was necessary for living as free men. The racial and sexual double standard that permitted white men to indulge themselves with black women (but denied white women and black men a comparable privilege) reinforced this symbolic division. Common-white men who used some form of coercion to gain sexual access to black women were strengthening the barriers between themselves and blacks. They were asserting power over blacks. They were asserting that "we can have access to your women but you cannot have access to ours." The legal system tolerated this practice as well. The law severely punished white women who bore mixed-race children; it left unpunished white men who fathered mulattoes.[13]

When law and custom tolerated common-white abuses of blacks but prevented blacks from replying in kind or even defending themselves, a clear message was being given: common whites could act like free men; blacks could not. However poor and degraded a white man might be, he could still rent a slave from one of his wealthy neighbors and expect deferential behavior from him. Should this behavior not be forthcoming, common whites could then take steps to coerce it.[14]

Common whites seeking to strengthen the barriers might turn to actions that humiliated or degraded blacks. In 1842 Lunsford Lane, a former slave, returned to Raleigh to buy some of his family and take them to the North. A mob, which one commentator called "some of our rowdies," met him. They accused him of preaching abolition and tarred and feathered him. After the mob had completed its task the mood changed. The people returned Lane's clothes, and, to his surprise, his watch. "They all expressed great interest in my welfare, advised me to proceed with my business the next day, told me to stay in the place as long as I chose, and with words of like consolation, bade me good-night. They felt that they had now degraded me to a level beneath themselves."[15]

Lane's comment was perceptive. The mob was interested in reminding Lane (and more importantly themselves) that his status was beneath theirs. Although he might have been a well-dressed, articulate man with contacts in some important places, he was still a black man whom they could abuse without fear of retribution. An unbridgeable gap separated them from him, and they were going to make sure the differences were widely known.

It is actions like these that lend credence to characterizations of the common whites as universally racist. And one cannot deny the pervasiveness of their racism. But one must keep in mind how racism helped to establish clear, definable boundaries between common whites and blacks. Common whites did not normally think of blacks as "the irreconcilable enemies of the whites" (to use the expression employed by the Incorporated Mechanical Society of Wilmington). But when boundaries were crossed, and when that crossing threatened the common-white position, they would take actions or make characterizations that rigidly and racistly defined the black sphere.

However pervasive these racist attitudes may have been, they tell only part of the story. If common-white racism insisted on perpetuating certain boundaries, there were, nevertheless, areas of social space allotted to blacks. Within those areas common whites and blacks could interact in a manner approaching equality and engage in behaviors that would challenge the rigid social boundaries in other areas. Different individuals, naturally, drew the lines in different places. A wide spectrum of beliefs about the appropriate distinctions between white and black emerged, challenging any notion that the common whites were uniformly, unthinkingly, or omnipotently racist.

At the extreme end of the spectrum were the religious antislavery advocates. They believed that not only were all people equal in the eyes of God but that society must structure itself along more equal lines by abolishing slavery. Levi Coffin, who grew up in the Quaker community of New Garden, Guilford County, recalled, "Both my parents and grandparents were opposed to slavery, and none of either of the families ever owned slaves; and all were friends of the oppressed, so I claim that I inherited my anti-slavery principles."[16] Coffin's antislavery principles led him to action. Although one might doubt his claim to being the president of the underground railroad, Coffin did help slaves escape their bondage at considerable personal risk. Coffin was exceptional, of course, and the Quaker sect to which he belonged was a minority, but Coffin was a common white who did what he could to end slavery.

Coffin was not alone. In 1807 Eli and William Copeland of Hertford County sought to free their mulatto slave because "they have considered for a length of time that it is incompatible with the tenets of Christianity" to enslave a man.[17] Not only were the Copelands sacrificing a substantial portion of their estate, they were also obliterating the basic distinction between themselves and this particular slave. They could not change his skin color; they could not change his manner of speaking, way of dressing, style of religion, or any number of other symbols that separated him from themselves. But they could undermine the greatest boundary between them; they could destroy the distinction whereby they were free and another man was a slave.

More typical examples of common-white resistance to slavery were ad hoc measures to help runaway slaves. Slaveholders were suspicious at times that local common whites had abetted their runaway chattel. An 1803 advertisement from Franklin County describes a slave and adds, "I have Reasons to believe that the Negro obtained a Pass from a trifling Person." Another advertisement from 1801 notes "The Negro is so well known in the Neighborhood of Waynesborough . . . where I presume he is harboured by white persons, that there needs no particular Description." [18]

When common whites had personal relationships with slaves, they might run the risk of assisting in escapes. This seems to have been more prevalent among common whites who shared degraded positions with blacks. Daniel O'Rafferty worked as a journeyman tailor in the same Craven County shop as a slave, Albert. O'Rafferty was said to be "greatly under the influence and control" of Albert who "possessed the entire confidence" of O'Rafferty. When his owner died in 1846, Albert convinced O'Rafferty that he was to be freed. O'Rafferty then tried to help his friend leave the state. O'Rafferty's Irish background may have led him to be more sympathetic with his friend's plight. As the former slave, Charity Austin, recalled of her youth in Granville County: "We children stole eggs and sold 'em during slavery. Some of de white men bought 'em. They were Irishmen and would not tell on us." [19]

At times common whites and slaves became a good deal more than friends. In 1825 Jim, a slave of Abraham Peppinger of Davidson County, and Polly Lane, a hired white girl on the farm, became lovers and planned to escape together. A visitor to the farm lost his pocketbook containing $260 and the consensus of those in the neighborhood was that the two had stolen the money in order to get away. Unfortunately for Jim, when the news broke, Polly abandoned him and accused him of raping her. When her mulatto child was born considerably less then nine months after the alleged rape, her story lost credibility.[20]

Common whites did not have to take dramatic measures to soften the lines separating them from blacks. Some common whites who would never have dreamed of helping slaves escape formed friendships with slaves that challenged the harsh racial boundaries. Children in particular seem to have been freer of the culture's stifling racism. In areas where lower-class whites, upper-class whites, and black children grew up together, one playmate might well be as good as another. Elias Thomas, an ex-slave from Chatham County, recalled: "we thought well of our poor white neighbors. We colored children took them as regular playmates. Marster's boys played with 'em too." After childhood some common whites continued the friendships they had started in their youth. Archibald Campbell, also of Chatham, was convicted of playing cards with a black man. A nonslaveholder, Campbell lived "in a section of country where the same thing is often done." In addition, Campbell's petition asserted that "[he] knew no difference between playing with a white man or sporting with a coloured one, not knowing that the laws of the county forbid the latter." Campbell was not the only common white to get in trouble with the law for this offense. The small slaveholders, Simon D. Pemberton and John Smith of Richmond County, were convicted because they "unlawfully did play at cards with certain slaves . . . to the evil example of all others." [21]

Twentieth-century sociological studies suggest that the poorest whites have not been the most virulent racists. Rather, the worst racists tend to be whites whose social position approaches the boundary between non-elite and elite status without fully entering the higher position. John Dollard noted in his 1937 study that blacks believed their real antagonists were "strainers." Those straining to get on in the world stressed racial differences because they were unsure of their own positions. The lowest-status whites also suffered various forms of discrimination and hence, developed a certain sympathy towards blacks. Studies of bigots corroborate Dollard's findings. Individuals with "authoritarian personalities" normally come from the lower-middle class. They are unsure of their own positions relative to those above and below them and feel safe only if everyone stays in his or her place. The lower-middle class, then, would be the group most dependent on overt social statements of racial superiority, not the lowest class. One should not assume that the poorest whites have been the staunchest proponents of rigid racial boundaries.[22]

The antebellum record seems to have been similar; associations between blacks and whites occurred with the greatest frequency among the poorest elements of the common whites. The Irish tailor who helped his black fellow journeyman to escape and the servant girl who stole a purse to bankroll her and her black lover's aborted flight did so because their sense of common plight allowed them to broaden their racial boundaries. This same sentiment was present in 1836 when two whites and three slaves joined forces and bored a passage out of the Tarboro jail. Feelings of a common plight were again present in Asheville where, according to George Swain (father of the future governor), a grog shop was so infamous that nobody went there "by daylight except Negros and Drunkards." In Fayetteville crime reports reveal relaxed color prohibitions in which some poor whites and blacks drank, whored, and plotted crimes together.[23]

Not only did low estate lead some common whites to disregard some of the racial boundaries, but so, too, did strong emotions and powerful passions. The common-white males' racial code set white women apart for themselves. This did not prevent some common-white women from having sexual relationships with black men. For example, Lewis Tombereau petitioned the State Legislature in 1824 for a divorce from his wife. The French-immigrant shoemaker living in Martin County described her in his petition as "one of the most frail, lewd, and depraved daughters of Eve." The petition claimed that she abandoned her husband, took up with a mulatto barber, and bore a racially mixed child. After this she "became and continues to be, a public and notorious prostitute in the most unlimited sense of that word. She [is] indulging in an unreserved, and promiscuous intercourse with men of every colour, age, class, and description she meets. In a similar instance John Hancock of Hertford County asked for a divorce from his wife, Tabetha, in 1813. The woman "abandoned herself to the most vile prostitution and debauchery—has had Children of various colours and complexions." A supporting statement added, "She Cohabbets and Equallises her Self with Mulattoes and Negroes in all Cases and . . . Lives at a Negro Quarter among Negroes."[24]

Despite enormous social pressures to the contrary, some common whites formed deep attachments with blacks. The divorce proceedings show numerous white women with black lovers, though this was probably because white men could more easily conceal forbidden love affairs than white women. Sometimes, however, the women did try. In 1821 Caleb Miller asked for a divorce from his wife Rachael. Six months after their marriage she gave birth to a child. Miller was away for much of the time, and Rachael kept the baby in a dark room. Although Miller did not suspect anything, local gossip began claiming that the child was a mulatto. He took it to a doctor, and another woman pronounced it black. In another case, Sarah Cowan of Rowan County gave birth to a mulatto child in 1794. Although it was clear to the neighborhood that the child was not white, "such was the exalted opinion which he entertained of the decency and virtue of his wife," that her husband, Isaac, "could not believe or harbor an unchaste thought" of her. He waited, and as the child grew older he saw that it was obviously not his own. He remained loyal and maintained hope of her repentance "until the birth of a second of the same hue with the first." In 1802 he asked for a divorce.[25]

It was not always necessary for children to bear witness to a woman's infidelity. Sometimes the women made no secret of their love affairs. In 1832 John Johnson of Orange County petitioned the legislature to dissolve his marriage, "being distitute of Land of his Own he was induced to become a Partner in a farm with a free Negro during which time his wife Peggy formed an attachment to said negro and consequently treated your Petitioner in such a way that he was forced to abandon her." Between 1800 and 1835, 7.5 percent of all divorces were granted for cohabitation with blacks.[26]

Common whites who formed romantic attachments with blacks did so at considerable risk. The story of John P. Waters and Elisabeth Culms cited earlier is one example of the consequences befalling those who violated their society's norms.

Most common whites did not fall in love with blacks. But many of them did interact with neighboring slaves and free blacks in a manner that approached equality and blurred of racial boundaries. Common whites and blacks attended churches together, prayed together, and went to revivals together. They might partake of the same extrareligious beliefs as well. For instance, James Reel of Pitt County, who owned a few slaves, regularly visited a black conjuror who told him he was being tricked by persons who wanted his property. The two groups might also join in illegal activities. Thomas Jones of Chowan County stole four pigs from his uncle and sold them to a free black woman.[27]

However, most of the joint thefts apparently worked the opposite way. Slaves would steal from their masters and sell or trade the goods to local common whites. The practice seems to have been commonplace. David Thomas of Bladen County ran into trouble in 1827 for trading with slaves. Thomas pointed out that he was a "very poor man," afflicted with rheumatism, "and if in this instance he has violated the laws of his County, he has done nothing more than what others more able to support themselves then he is are in the daily habit of doing, with impunity."[28]

To engage in this kind of traffic, common whites and slaves had to develop a relationship and trust to carry on the exchanges and avoid getting caught. One ex-slave from Wake County complained that sometimes owners made blacks violate this trust. A master might force a slave to take things from his house and sell or trade them to local common whites. Then the slaveholder would come along, discover his property, and swear out a writ. The owner would then give the poor white the chance to sell out to him and leave or face the consequences.[29] But this kind of setup was probably rare.

Not only did the slaves and common whites have to develop a degree of trust, but they also had to engage in a comparable amount of planning. In 1844 in Northampton County, James Hart found himself on trial for trading stolen goods with a slave. A witness described what had taken place: about two hours before dawn a slave took a bag of cotton and a jug to Hart's house. A short while later the slave left the house with an empty bag and a full jug.[30] No slave would have ever gone up to a strange house in the middle of the night with a bag of stolen cotton. The transaction had to have been arranged some time before.

The common whites in these situations were in effect hiring slaves to steal from their masters. However much they might dislike blacks, the common whites' greed and hostility towards the planters prompted them to make common cause with blacks. William D. Valentine recalled that when he was a boy on his father's eastern plantation "a few mean and occasionally scoundrally families did for a long time keep a familiarity and traffic with our black portion of the family. There were no other negroes in the neighborhood." The Valentines, the only slaveholders in the neighborhood, were a ready target for common-white hostility. The traffic with slaves was in many ways comparable to the poaching that supplemented the diets of eighteenth-century Englishmen. One could not injure the interests of another lower-class Englishman by poaching game, only the interests of the lord who owned it. Similarly, nonslaveholders could not be injured when slaves stole goods from their masters and traded them to common whites. In both cases the law served to protect the interests of the ruling classes at the expense of the lower classes. Yet the common whites had sufficient solidarity to tolerate the practice of trading stolen goods with blacks. When their numbers were large enough they might refuse to convict offenders or merely slap them on the wrist. Apparently the trade was impossible to curtail. A group of planters from Pasquotank County complained in 1848: "Efforts have been made, and are constantly being made by our citizens to bring these offenders to justice, some times successfully—but not to such an extent as to remedy the evil." [31]

The common whites' ability to get along well enough with neighboring blacks calls into question blanket assumptions about their racism. They did not have to like blacks in order to hire them to steal. But common whites did have to be willing to treat them with a modicum of respect and dignity. Blacks certainly did not have to go to a particular common white with their stolen goods. Unless he treated them decently, there was little reason to suppose slaves would keep coming back. By trading with slaves common whites were allowing the racial boundaries to become fuzzy. Their own self-interest demanded that they see slaves as sharing in a common predicament.

The common whites, then, were willing to let the boundaries between the races become blurred when it was in their own interest. When they could get a particular good at a cheap price (and have the added pleasure of causing a neighboring planter fits), they would lower the barriers. When they could get love or friendship at a time when they felt alone in the world or during some other curious set of circumstances, they would abandon the sharp lines of racial separation in favor of ones that were less distinct. Here, then, were the limits of racism.

The common whites' perceptions of slavery were scarcely monolithic. They were quite aware that slavery was anything but a benign system for upgrading the welfare of contented blacks. In 1845 the leading Democratic Party newspaper, the *North Carolina Standard,* which claimed to be the advocate of the common man's interests, printed a joke under the heading "African Candor." The joke describes a conversation between a slave named Cudjo and his master. The master asks him if he had attended church. Cudjo says he had and adds, "an' what two mighty big stories dat preacher did tell." The master asks him what stories (that is, what lies) the preacher told. "Why he tell the people no man can serve two massas—now dis is de fuss story, 'cause you see Old Cudjo serves you, my old massa, an' also young massa John. Den de preacher says, 'he will lub de one and hate de other' while de Lord knows, *I hate you boff.*" At one level, common whites recognized that the slaves had every reason to despise the men who enslaved them.[32]

Common whites were not unaware of the horrors that took place in slavery. Their general reaction was to ignore them, rationalize them, or even participate in some of them. But at the same time common-white culture recognized that slavery could be a cruel system capable of making a man insane. A folk tale collected in Burlington in the 1930s illustrates the cultural memory that existed long after slavery had ended. The story tells of an A. M. Duncan, who allegedly lived around 1800. Duncan was known to be cruel to his slaves. He hung them by their thumbs in the smokehouse; he would cut off their ears and hang them up. He was alleged to have twenty pairs of black ears hung in that smokehouse alone. He would tie his slaves to stakes, beat them with a cat-o'-nine-tails, and rub salt and vinegar on the wounds.

Duncan's favorite target was a slave named Crazy Sam. Sam was a mulatto; some said he was Duncan's half-brother. Such talk only made Duncan beat him more frequently. One moonless night Sam had taken enough. He went to the master's bedroom and drove an ax into the head of the person asleep on the bed. Unfortunately for Sam, he had not killed Duncan but a boy who lived with him. The next morning Duncan came with gun in hand, looking for the murderer. Sam rushed Duncan with his ax and split his master's head to his shoulders.

Word of the incident reached the community. The neighbors and constable came. Sam held them off with Duncan's gun and killed the constable. Stray shots hit another white man, Sam's wife, and his children. Finally, Sam was killed. According to legend, from then on the house was haunted. Every night Duncan's ghost would bind Crazy Sam's ghost to the whipping stake, lash him, pour salt on his cuts, and hang him by the thumbs in the smokehouse. Any traveller hearing Sam's screams would be instantly turned stone deaf.[33]

The folktale says a great deal about the people who created it. The common whites thought of slavery as a brutal institution that might drive men crazy. Crazy Sam apparently lost his sanity under the pressure from his tormentor. Sam murdered his master, but his response did not seem unreasonable. Clearly the brute in the story was Duncan, not his black slave. Although the story showed the common whites' sympathy for the plight of the slave, it also showed that they would not allow the slaves to resort to insurrection to alter their condition. The community rallied to kill Sam even though they knew what kind of beast his owner was. Common whites were willing to defend slavery even though they might believe it was wrong. In general, this was the common-white view of slavery. Although they approved of the institution's ability to define the black place in society, they also recognized the essential inhumanity inherent in the system. Elmina Foster's recollections of her childhood attitudes towards slavery were probably typical of many common whites. Although she grew up in a nonslaveholding family of Quakers, she remembered pitying the slaves' conditions: "Brought up as I was in a slave holding neighborhood, accustomed to seeing slaves at work on all sides, in the fields, I supposed conditions to remain the same always, for slavery was a vast, far reaching thing, so deeply entrenched in society, it did not seem possible that it should ever be eradicated." [34]

Endnotes

[1]This petition is found in Legislative Papers North Carolina State Division of Archives and History, Raleigh, NC, Box 192 (hereafter cited as LP 192).

[2]LP 237.

[3]For a more thorough discussion of the definition of common whites see Bill Cecil-Fronsman, "The Common Whites: Class and Culture in Antebellum North Carolina," Chap. 1 in Ph.D. diss., University of North Carolina, Chapel Hill, 1983.

[4]William L. Barney, *The Secessionist Impulse: Alabama and Mississippi in 1860* (Princeton: Princeton University Press, 1974), pp. 229–30; William J. Cooper, Jr., *Liberty and Slavery: Southern Politics to 1860* (New York: Alfred A. Knopf, Inc., 1983), p. 249.

[5]Eugene D. Genovese's theories of paternalism are best stated in *The World the Slaveholders Made: Two Essays in Interpretation* (New York: Alfred A. Knopf, 1969), Book II. For an alternative reading of the slaveholders that emphasizes the harsher side of their racism see James Oakes, *The Ruling Race: A History of American Slaveholders* (New York: Alfred A. Knopf, 1982). The quotations from Hahn are from Steven Hahn, *The Roots of Southern Populism: Yeoman Farmers and the Transformation of the Georgia Upcountry, 1850–1890* (New York: Oxford University Press, 1983).

[6]Pierre L. van den Berghe, *Race and Racism: A Comparative Approach* (New York: John Wiley & Sons, Inc., 1967), Ch. 1. George Fredrickson has stated his position in several places. A good introduction to his use of the *herrenvolk* concept is *The Black Image in the White Mind: The Debate on Afro-American Character and Destiny, 1817–1914* (New York: Harper & Row, 1967), pp 58–70.

[7]There is, of course, an extensive literature on racism. In addition to the works cited in this article, I have found James M. Jones, *Prejudice and Racism* (Reading, Mass.: Addison-Wesley, 1972) to be of particular help. Space limitations prevent a discussion of the process by which these norms evolved within common-white culture. See Cecil-Fronsman, "The Common Whites," chapter 3 on this point. Readers should note that most scholars believe that however racist common whites may have been in the antebellum period, their descendants were far more racist in the postbellum pe-

riod. See Joel Williamson, *The Crucible of Race: Black-White Relations in the American South Since Emancipation* (New York: Oxford University Press, 1984).

[8]LP 312.

[9]LP 631.

[10]Newman Ivey White, gen. ed., The *Frank C. Brown Collection of North Carolina Folklore* (Durham, NC: Duke University Press, 1952, 1961), III 508. See also George P. Rawick, ed., *The American Slave: A Composite Autobiography* vols. XIV and XV: *North Carolina Narratives* (Westport, Conn.: Greenwood Publishing Co., 1972) (hereafter cited, Rawick, *NC Narratives*) XIV 424 where a former slave discusses how slave patrollers sang this song.

[11]Roy Johnson, "A Sampling of Eastern Oral Folk Humour," *North Carolina Folklore Journal* XXIII (1975):5.

[12]This incident is well discussed in John Scott Strickland, "The Great Revival and Insurrectionary Fears in North Carolina: An Examination of Antebellum Southern Society and Slave Revolt Panics," *Class, Conflict, and Consensus: Antebellum Southern Community Studies,* ed. Orville Burton and Robert C. McMath, Jr. (Westport, Conn.: Greenwood Publishing Co., 1982), pp 62–63.

[13]See Katherine Ann McGreachy, "The North Carolina Slave Code," Master's thesis, University of North Carolina, Chapel Hill, 1948.

[14] This practice was confirmed by the North Carolina Supreme Court in the case of *State v. Jowers* 11 Iredell 55 [1850].

[15]William G. Hawkins, *Lunsford Lane: or Another Helper From North Carolina* (New York: Negro Universities Press, 1969 [1853]), p. 156. The comment about the mob is by David W. Stone and is found in a letter to Supreme Court Chief Justice, Thomas Ruffin. See J. G. deRoulhac Hamilton, ed., *The Papers of Thomas Ruffin* (Raleigh: Publications of the North Carolina Historical Commission, 1918) II 205.

[16]Levi Coffin, *Reminiscences of Levi Coffin: The Reputed President of the Underground Railroad,* 2d ed. with appendix (Cincinnati: Robert Clarke & Co., 1880), p. 11.

[17]LP 226.

[18]*Raleigh Register* 12-12-1803, 1-17-1801.

[19]Governors Papers, North Carolina Division of Archives and History, Box 116 n.d. [1846] (hereafter cited as GP 116); Rawick, *NC Narratives* XIV 59.

[20]See documents in GP 55.

[21]Rawick, *NC Narratives* XV 345; GP 94; State v. Pemberton and Smith 2 Devereux 281 [1829].

[22]John Dollard, *Caste and Class in a Southern Town.* 2d ed. (New York: Harper & Brothers, 1937, 1949), p. 77–78; Joel Kovel, *White Racism: A Psychohistory* (New York: Pantheon Books, 1970), p. 56.

[23]*North Carolina Standard* 1-11-1836; George Swain to David Swain 8-16-1822, Swain Collection, Southern Historical Collection, University of North Carolina; Harry L. Watson, *Jacksonian Politics and Community Conflict: The Emergence of the Second American Party System in Cumberland County, North Carolina* (Baton Rouge: Louisiana State University Press, 1981), p. 44.

[24]LP 377; LP 276.

[25]LP 336; LP 192.

[26]LP 485; Guion Griffis Johnson, *Ante-Bellum North Carolina: A Social History,* (Chapel Hill: University of North Carolina Press, 1937), p. 211.

[27]*Reel v. Reel* 2 Hawkes 53 [1822]; State v. Jones 3 Dev. and Bat. 2 [1833].

[28]LP 415.

[29]Rawick, *NC Narratives* XIV 319.

[30]*State v. Hart* 4 Iredell 246 [1844].

[31]William D. Valentine Diary, 10-23-1842, Southern Historical Collection, University of North Carolina; Eugene D. Genovese, *Roll, Jordan, Roll: The World the Slaves Made* (New York: Pantheon Books, 1974), p. 642; LP 637. On poaching see Douglas Hay, "Poaching and the Game Laws on Cannock Chase," *Albion's Fatal Tree: Crime and Society in Eighteenth-Century England* ed. Douglas Hay et al., (New York: Pantheon Books, 1975), pp. 202–12.

[32]*North Carolina Standard* 11-5-1845.

[33]This remarkable tale was collected by an anonymous Federal Writers Project writer from Flora Fowler of Burlington. It is printed as "The Old Duncan House," *North Carolina Folklore* 1(1948):7–8. It is impossible to tell with complete certainty whether this tale was fashioned before or after the Civil War. The references to slavery and the year 1800 suggest that it had antebellum origins. Moreover, a similar tale was collected in Lincoln County, Kentucky, which sets the incident about the same time. See William Lynwood Montel, *Ghosts Along the Cumberland: Deathlore in the Kentucky Foothills* (Knoxville: University of Tennessee Press, 1975), p. 117. There were no A. M. Duncans living in Alamance County, where Burlington is located, nor were there any in Orange County, the county from which it was formed. A. M. Duncan may be a corruption of

Duncan Cameron, a distinguished Orange County planter from the early nineteenth century. His reputation, however, was one of gentleness to his slaves and unlike the character in the story, he had seven children. See William S. Powell, ed., *Dictionary of North Carolina Biography* (Chapel Hill: University of North Carolina Press, 1979), 1:311. The story is clearly a white folktale. The 1943 Burlington city directory lists Florence Fowler as white.

[34]Elmin Foster Reminiscences, Typescript, Southern Historical Collection, University of North Carolina, p. 7.

Fluctuations of a *Peromyscus Leucopus* Population Over a Twenty-Two Year Period

James W. Popp, Paul E. Matthiae, Charles M. Weise, and James A. Reinartz

Abstract. *Fluctuations in population size of a* Peromyscus leucopus *population in southeastern Wisconsin over a twenty-two year period were determined by annual live-trapping. The population exhibited moderate fluctuations in size, but there was no evidence for regular or cyclic fluctuations. A severe ice storm in the middle of the study period caused dramatic changes in the woodland habitat of the population under study. Fluctuations in population size increased after the ice storm, with the largest relative increase in population size occurring immediately after the ice storm.*

Peromyscus populations have traditionally been thought to be relatively stable (Terman 1968). Recent studies indicate, however, that populations of *Peromyscus leucopus* may exhibit fluctuations of over ten fold in population size (Sexton et al. 1982; Wolff 1985, Vessey 1987). Some authors suggest these fluctuations may reflect regular or cyclic fluctuations similar to those reported for microtine rodents (Wolff 1985).

A better understanding of population fluctuations in *P. leucopus* has been hampered by the paucity of long-term studies of the species. In this study, we report results of twenty-two years of annual live-trapping data for a *P. leucopus* population in southeastern Wisconsin. Our analysis centered on two areas. First, we investigated the magnitude of population fluctuations and whether these fluctuations were regular or cyclic using the criteria of Henttonen et al. (1985). Second, we examined what effect a major change in habitat, caused by a severe ice storm in the middle of the study period, had on the magnitude of population fluctuations. *Peromyscus leucopus* is a habitat generalist, found in habitats ranging from grasslands to mature forest (Adler and Wilson 1987). The species shows a preference for wooded habitats with complex vertical structure, including a definite shrub layer and presence of fallen trees, stumps and logs (M'Closkey and Lajoie 1975; Kaufman et al. 1983). An ice storm in 1976 resulted in increased canopy openings, increased density of herbaceous and shrub species, and increased the number of fallen branches and dead trees. The ice storm generally improved habitat quality for *P. leucopus* in the study area.

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Methods

This study was conducted between 1966 and 1987 at the University of Wisconsin-

Milwaukee Field Station, Ozaukee County, Wisconsin. The study area was in mature upland forest dominated by sugar maple *(Acer saccharum)*, white ash *(Fraxinus americana)*, American beech *(Fagus grandifolia)*, basswood *(Tilia americana)*, hophornbeam *(Ostrya virginiana)* and shagbark hickory *(Carya ovata)* (Dunnum 1972). Live-trapping was done on a 0.5625 ha grid. The grid consisted of 25 trap stations, 15 m apart in a 5 × 5 array. From 1966 to 1979, two Sherman type traps were placed on the ground at each station; from 1980 on, two Longworth traps were used at each station. Trapping was conducted in September or early October of each year. No trapping was done in 1980, and insufficient data were collected for analysis in 1985 because of heavy trap raiding by raccoons *(Procyon lotor)*. Animals received temporary ear marks. Trapping was done as a class demonstration but was always conducted by one of the authors and was standardized.

Population sizes were estimated using the Bayesian approach of Gazey and Staley (1986). We used the standard deviation of the logarithm of population size *(s)* to test for regular or cyclic fluctuations (Henttonen et al. 1985). Henttonen et al. (1985) have shown that a value of *s* greater than 0.5 is a good indicator of cyclic fluctuations in microtine populations. In March 1976, a severe ice storm occurred at the study site, which caused considerable damage to the trees. Before the storm, the canopy was essentially closed, herbaceous vegetation was low, and shrub cover was patchy at a low density, with little downed wood or litter on the forest floor. After the ice storm, macro-litter volume of downed wood on the floor was 19.4 m^3/ha, which accounted for a loss of approximately 35% of the canopy (Bruederle and Stearns 1985). Because of the greatly increased light penetration after the canopy loss, the herbaceous and shrub cover increased.

Results

Population sizes of *P. leucopus* exhibited moderate fluctuations (Fig. 1). The greatest continuous increase in population size was between 1976 and 1978, when a 3.2-fold increase occurred (peak population size/previous low size), following the ice storm of March 1976. Annual changes in population size (higher population size/lower population size) ranged from 1.0 to 2.9 (mean = 1.8, SD = 0.66). There was no evidence for cyclic or regular fluctuations. The value of *s* was 0.18, which is well below the 0.5 used by Henttonen et al. (1985) to distinguish cyclic populations.

Annual fluctuations in population size appeared to be greater in the years after the ice storm. A comparison of mean annual change in population size for 1966–1976 and 1977–1987 support this suggestion. Mean fluctuations were greater for the period after 1977 (1966–1976: mean = 1.41, SD = 0.45, versus 1977–1987: mean = 2.11, SD = 0.72; T-test: t = 2.39, d.f. = 14, $P < 0.05$). When comparing years in which population size increased, the mean finite rate of increase was greater after the ice storm (1966–1976: mean = 1.52, SD = 0.57, versus 1977–1987: mean = 1.98 SD = 0.69). This difference, however, is not significant, probably because of the small sample size (t = 1.09, dif. = f, $p > 0.05$). Mean population size was not significantly different between the two periods, but the variance of the population size was different (1966–1975: mean = 36.13, SD = 10.09, versus 1977–1987: mean = 47.13, SD = 21.26; T-test for unequal variances: t = 1.42, d.f. = 11.2, $P > 0.05$; F-test: F = 4.44, d.f. = 8.9, $P < 0.05$). Values of *s* calculated for before and after the ice storm showed greater variation after the ice storm but still provide no evidence for regular fluctuations (1966–1975: *s* = 0.15; 1977–87: *s* = 0.20).

Discussion

The *P. leucopus* population under study exhibited moderate fluctuations in population size. The fluctuations were, however, not as great as recently reported for other populations (Sexton et al. 1982; Vessey 1987). The fluctuations observed in this population showed

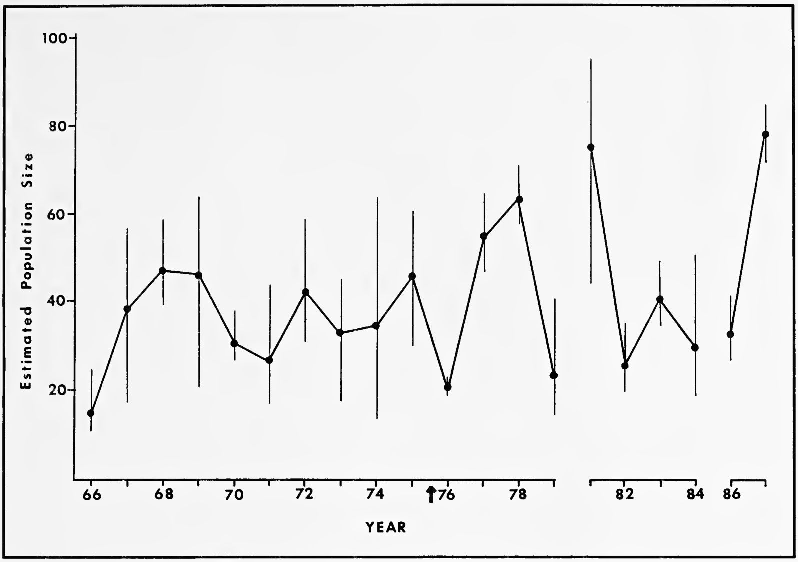

Fig. 1. Estimated size of a population of Peromyscus leucopus in southeastern Wisconsin over a twenty-two year period. Vertical bars represent .05 and .95 quantiles. The arrow indicates occurrence of ice storm.

no evidence of being regular or cyclic and probably reflect annual changes in population size rather than multiannual cycles. The value of *s* from this study (0.18) was within the range of values previously reported for this species. Values reported have ranged from 0.07 to 0.56, with most values between 0.16 and 0.27 (Ostfeld 1988).

The occurrence of the ice storm in the middle of this long-term study provided an opportunity to examine the effects of a large change in the environment on the size fluctuations of a population. Although in this study the mean population size was not significantly greater after the ice storm, the population had its greatest increase in size after the ice storm, presumably because of improved habitat conditions. After this peak, the population then experienced a series of its largest size fluctuations, perhaps representing a period of instability as the population adjusted to the new environmental conditions.

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The Aquatic Macrophyte Community of Black Earth Creek, Wisconsin: 1981 to 1986.

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Abstract. *The biomass and relative species abundance of the submersed aquatic macrophyte community of Black Earth Creek, Wisconsin were examined in 1986 at three sites and compared to data gathered in 1981 and 1985. Although total biomass was significantly lower in 1986 than 1985, the relative frequency of species was similar from 1981 to 1986. Macrophyte species are segregated along the length of the stream, with* Potamogeton crispus *dominant upstream and* Potamogeton pectinatus *dominant downstream, due to changes in water temperature. In reviewing species associations for Wisconsin streams,* P. crispus *and* P. pectinatus *were typical of eutrophic streams, and native species were typical of unimpacted mesotrophic streams. In summary, this study indicates that although total macrophyte biomass and abundance may fluctuate dramatically due to physical events (e.g., flooding), the relative frequency and dominance of species both spatially and temporally remain relatively constant.*

Although studies of submersed aquatic macrophytes in lakes are relatively common, studies of the ecology of this group of plants in streams are relatively rare. This paucity of research on stream macrophytes does not reflect the importance of controlling stream ecosystem structure and processes (Westlake 1973, 1975). Macrophytes are important to productivity in some stream systems and may play an important role in nutrient dynamics, particularly phosphorus (Dawson 1976; Minshall 1978; Madsen 1986). Macrophytes provide habitat for fish and macronivertebrates (Dawson 1978; Haslam 1978) and are substrate for epiphytic microflora that control water column chemical processes and contribute to primary productivity and community oxygen metabolism.

Within the state of Wisconsin, relatively few studies on stream macrophytes have been published. In the northeast, Smith (1978) studied the distribution of submersed macrophyte species in the Pine and Popple River systems. He found stream communities to be dramatically different in composition from adjacent lake communities. In a Wisconsin Department of Natural Resources (WDNR) report, Mace et al. (1984) discussed the results of an intensive survey of submersed

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macrophytes in southeastern Wisconsin streams in which they modeled biomass and community oxygen metabolism based on nutrient loadings from point sources. In another WDNR study, Hunt (1979) indicated that the removal of streamside woody vegetation improved trout fisheries by stimulating stream macrophyte growth. Badfish Creek has been studied for several years, first by Madison Metropolitan Sewerage District staff, and subsequently in dissertation work by Madsen (1986).

Of the macrophyte communities in all Wisconsin streams, that of Black Earth Creek has been most extensively studied. Field studies on the macrophyte community of Black Earth Creek were conducted in 1981 (Madsen 1982; Madsen and Adams 1985) and in 1985 in conjunction with a joint program by the WDNR, U.S. Geological Survey (USGS), and the University of Wisconsin-Madison Institute for Environmental Studies Water Resources Management Workshop (Born 1986; Bouchard and Madsen 1987). In 1986, this study was conducted in conjunction with further studies by the USGS. Relative frequency data for 1981 and both biomass and relative frequency data for 1985 and 1986 allow for inter-annual comparisons. In addition, data from various stream sites throughout the summer allow a comparison of species distribution and seasonal succession between years.

Plant biomass and species composition in streams may be sensitive to many factors; however, most factors do not change greatly from year to year. For instance, plant productivity and resultant biomass is often light-limited, yet the shading regime of a given stream changes little from year to year, barring windthrow or human activity (Peltier and Welch 1969; Kullberg 1974; Ham et al. 1982). However, flooding events of varying magnitude and duration may greatly affect species composition and total biomass of macrophytes both within a single year and from year to year (Bilby 1977; Dawson et al. 1978). Therefore, historical events are the most important factors explaining year-to-year variation in total biomass and species succession.

Materials and Methods

Site Description

Black Earth Creek is located in south-central Wisconsin in the western portion of Dane County (Fig. 1) on the edge of the nonglaciated "Driftless Area." Black Earth Creek is a calcareous, highly productive stream classified as a "class-one" trout habitat, meaning that natural reproduction maintains the trout population (Brynildson and Mason 1975). It is undoubtedly the most productive trout stream in Wisconsin and, coupled with its location close to Madison, one of the most important trout fishery resources in the state (Born 1986).

The baseflow of the stream is predominantly groundwater and artesian spring flow. Storm runoff and overland flow may produce substantial flooding. Land use in the drainage basin is predominantly agricultural (Born 1986).

In this study, biomass was sampled at three of the sites used in the 1985 study: sites 1,

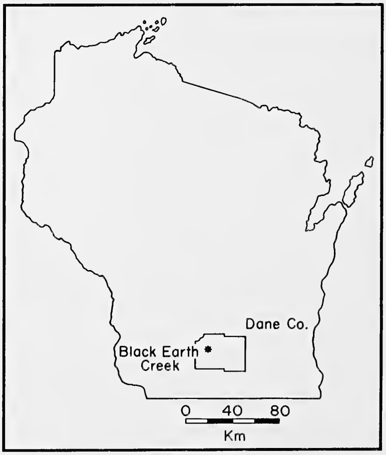

Fig. 1. Location of Black Earth Creek in Wisconsin.

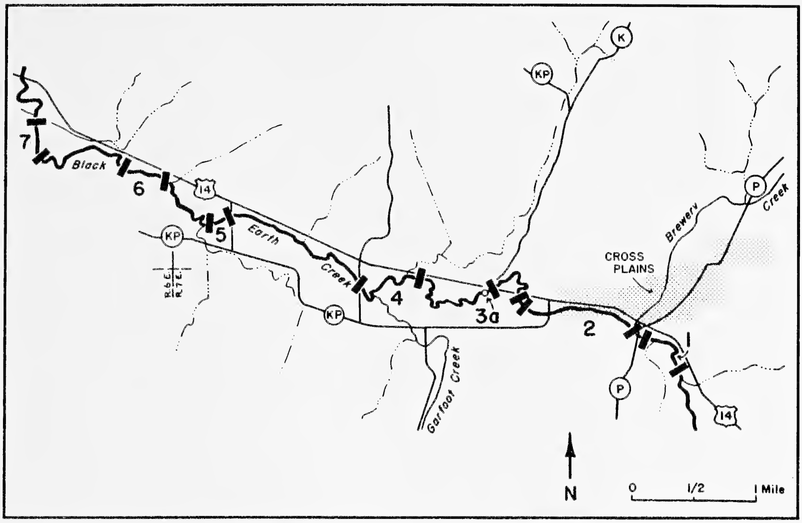

Fig. 2. Sample sites on Black Earth Creek.

3 (labeled 3a), and 7 (Fig. 2). Biomass data from 1986 were compared to biomass data from 1985 sampled at sites 1, 3, and 7 (Bouchard and Madsen 1987; Born 1986), and relative frequency data from biomass samples in 1986 were compared to relative frequency data from cover for sites 1 through 7 from 1985 and sites 1 through 4 from the 1981 study (Madsen 1982; Madsen and Adams 1985).

Methods

At each sample site, twenty biomass samples were taken based on a stratified-random pattern, sorted to species, and dried at 70°C to constant weight. Biomass was sampled on three dates during the summer of 1986: 23 June, 15 July, and 7 August. Relative frequency of each species, a measure of dominance, was calculated as a percentage of total biomass. Relative frequency from biomass is comparable to, but not the same as, relative frequency from cover. Although these values are compared, no statistical tests are used in the comparison of relative frequency data due to this difference.

Species nomenclatrue is based on Gleason and Cronquist (1963), although Fassett (1957) and Voss (1972) were used for initial indentification. Species observed in Black Earth Creek in 1986 were *Callitriche stagnalis* Scop., *Elodea canadensis* Michx., *Potamogeton crispus* L., *Potamogeton pectinatus* L., *Ranunculus longirostris* Godr., and *Zannichellia palustris* L. Voucher specimens were deposited in the University of Wisconsin-Madison herbarium.

Results and Discussions

Total Biomass

Total submersed macrophyte biomass was significantly higher at sites 1 and 7 in 1985 than in 1986 (789 and 512 vs. 323 and 19 g dw m^{-2}, respectively), while site 3 shows little variation between the years (335 vs. 347 g dw m^{-2}, respectively; see Fig. 3). Since biomass for 1985 was sampled on 1 July 1985, this value is best compared to the biomass for 23 June 1986. We interpret this wide divergence in biomass to be the result

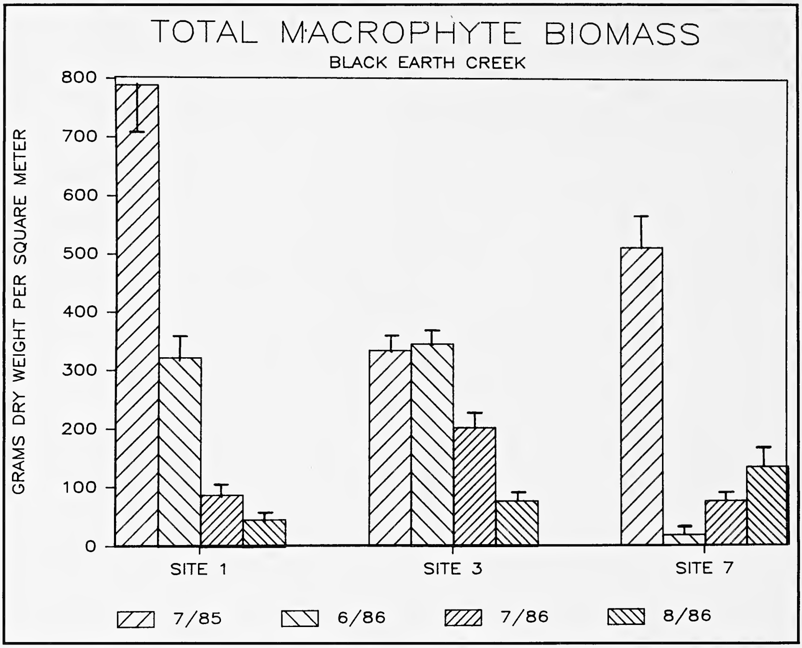

Fig. 3. Total biomass in Black Earth Creek at sites 1, 3, and 7 for 1985 and 1986. Bars indicate +1 standard error.

of flooding after a major storm on 25 July 1985 (Steven Field, USGS, pers. comm.). The flood scoured the soft sediments at sites 1 and 7, removing both the plant shoots present and the propagules in the sediment resulting in lower biomass the following year. Site 3, with its more stable gravel substrate, was relatively unaffected in terms of sediment scour.

Biomass at sites 1 and 3 peaks in late June due to the early phenology of its dominant species, *P. crispus,* which peaks in mid-June and senesces by mid-July (Sastroutomo 1981). *Potamogeton pectinatus,* the dominant at site 7, peaks in early August (134 g dw m^{-2}), as has been observed for *P. pectinatus* in nearby Badfish Creek (Madsen 1986).

Interannual Species Dominance

Despite the large variation in total biomass, the relative frequency of species has varied little over the five-year period examined (Fig. 4). The species, *P. crispus* and *P. pectinatus,* have remained dominant throughout the period. Some variation can be explained by a shift in methodologies; 1981 and 1985 data were computed from cover data gathered over extensive reaches, whereas 1986 data were calculated from biomass from more limited stretches. For instance, *R. longirostris* is commonly found in riffle areas, a habitat that is underrepresented within biomass sample sites. Also, 1981 data were collected for only sites 1 through 4, emphasizing reaches in which *P. crispus* is dominant. Lastly, distinct but minor changes in species occurrence have been observed between the years. *Elodea canadensis* was below one percent of the total cover for sites 1 through 4 in 1981 but now is frequently found in those stretches. The two dominant species have changed little.

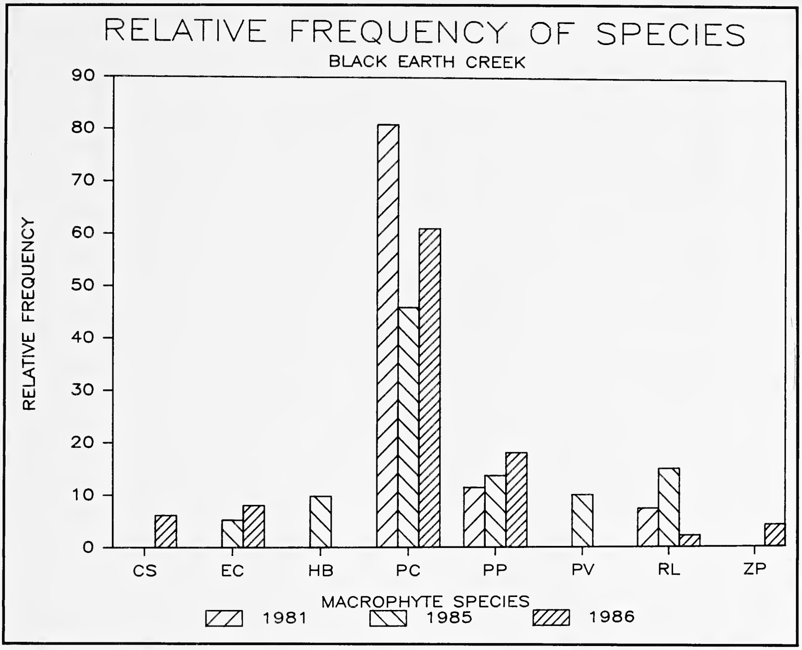

Fig. 4. Relative frequency of macrophyte species for 1981, 1985, and 1986. Species codes: CS, Callitriche stagnalis*; EC,* Elodea canadensis*; HB,* Hypericum boreale*; PC,* Potamogeton crispus*; PP,* Potamogeton pectinatus*; PV,* Potamogeton vaginatus*; RL,* Ranunculus longirostris*; ZP,* Zannichellia palustris.

Flooding acts to initially remove shoot biomass in the first year. This effect is definitely differential with respect to species, resulting in a change in species composition (Bilby 1977; Madsen and Adams 1985). However, the primary effect is to remove biomass. A major flooding event could affect biomass the following year if a sufficient proportion of propagules were also removed, as apparently happened in 1985–1986. Theoretically, a major flooding event could alter species composition in following years if flood scour had a differential impact on the proportion of propagules of each species removed. In this instance this was not observed. Species composition has been relatively stable from 1981–1986. One factor in this stability could be the overwintering adaptations of the dominant species (Table 1). The only species that reproduce significantly by seed are those inhabiting the edges of the stream or very stable substrates (e.g., *C. stagnalis* and *Z. palustris*). The other four species are cited by Haslam (1978) as flood tolerant. *Elodea canadensis* is generally found in sheltered sites and can overwinter as either dormant apices above the sediment level or as dormant rhizomes. *Ranunculus longirostris* also utilizes dormant shoots but is mostly found in very stable substrates. The two dominants, *P. crispus* and *P. pectinatus,* are capable of overwintering in dormant structures under the sediment surface that are resistant to all but heavy scour. These two species also produce an abundance of highly dispersable propagules, which are an important aspect of their ability to dominate in eutrophic waters. None of these last four species appears to

Table 1. Forms of overwintering propagules and flood tolerance (Haslam 1978) for submersed macrophyte species in Black Earth Creek.

Species	*Propagule*	*Reference*
Callitriche stagnalis	Fruit/Seed	Voss 1985
Elodea canadensis	Dormant Apices Turions Rhizomes "Flood Tolerant"	Haslam 1978 Sculthorpe 1967 Engel 1985
Potamogeton crispus	Turions Rhizomes "Flood Tolerant"	Haslam 1978 Sculthorpe 1967
Potamogeton pectinatus	Tubers Rhizomes "Flood Tolerant"	Voss 1972 Haslam 1978
Ranunculus longirostris	Dormant Stems Dormant Apices "Flood Tolerant"	Haslam 1978
Zannichellia palustris	Fruit/Seed Significant Seed Production	Voss 1972 Hutchinson 1975

have propagules more tolerant of flood scour than the others.

Drastic changes in the species composition of Black Earth Creek would result from changing the light regime. Open stretches, which are common, tend to form the highest biomass and to be dominated by either *P. crispus* or *P. pectinatus*. By allowing riparian tree vegetation to grow, a more diverse community with lower biomass would result. Such a management strategy would be employed if macrophyte biomass was considered so high as to be deleterious to the the trout fishery (Born 1986; Bouchard and Madsen 1987). Still, a certain amount of macrophyte biomass is desirable (White and Brynildson 1967; Hunt 1979), and we suggest the best strategy would be to allow a mixture of open areas with high macrophyte biomass and shaded areas of lower biomass and higher plant diversity.

Seasonal Succession–1986

Seasonal succession follows a fairly consistent pattern in Black Earth Creek (Fig. 5). *Potamogeton crispus* dominates throughout most of the stream in June and begins senescing by mid-July. By August, *P. crispus* biomass is only in the form of dormant and propagules. Other species peak after *P. crispus* based on their distribution within the stream, with *E. canadensis* or *P. pectinatus* being a common late season dominant. The late season dominants for sections 1 and 3 were *E. canadensis* or remaining *P. crispus* biomass, while *P. pectinatus* continued to dominate at site 7 throughout the season, as has also been observed at Badfish Creek (Madsen 1986). Discriminant analysis indicated three species as having significant seasonal changes in biomass: *P. crispus* ($p = 0.0000$), *P. pectinatus* ($p = 0.0036$), and *E. canadensis* ($p = 0.0889$). This type of seasonal pattern was observed in 1981, except that *E. canadensis* was not a significant component of the community at that time, and flooding removed most of the submersed macrophyte cover in early August of 1981.

Distribution between Sites–1986

As mentioned before, *P. crispus* was the dominant species in sites 1 and 3, and *P. pectinatus* was the dominant at site 7 (Fig. 6). Among the nondominant species, only *R. longirostris* had a significant presence at site 7. The near-monoculture of *P. pectinatus* at

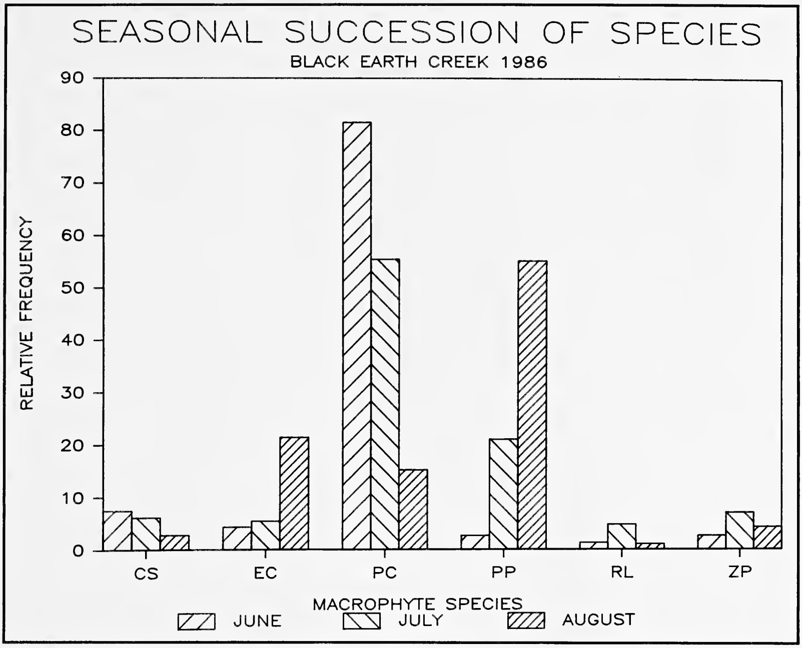

Fig. 5. Seasonal succession of species in Black Earth Creek during 1986 as based on relative frequency. Species codes: CS, Callitriche stagnalis*; EC,* Elodea canadensis*; PC,* Potamogeton crispus*; PP,* Potamogeton pectinatus*; RL,* Ranunculus longirostris*; ZP,* Zannichellia palustris.

site 7 was also observed in 1985, except that *P. vaginatus* was also present in significant proportions. *Potamogeton vaginatus* was seen at site 7 in 1986 but not quantified. *Potamogeton pectinatus* often forms a dense monoculture in warmer eutrophic streams (e.g., Badfish Creek, Madsen 1986), whereas *P. crispus* tends to be the dominant species in cooler eutrophic environments. The dominance of *P. crispus* at sites 1 and 3 is consistent with observations made in 1981 and 1985. Discriminant analysis indicated that all species except *R. longirostris* ($p = 0.1398$) were significantly different in their biomass distributions between the three sites (e.g., $p \leq 0.05$), indicating the sharp divergence of vegetation in sites 1 and 3 from that in site 7.

Increased water temperature is the environmental factor most likely responsible for the shift in dominance from *P. crispus* at sites 1 and 3 to *P. pectinatus* at site 7. Although both *Potamogeton* species are common dominants in eutrophic, high alkalinity waters, *P. crispus* tends to be dominant either in cooler lakes and streams or earlier in the season while water temperatures are low (e.g., Sahai and Sinha 1976; Engle 1985; see Table 2). In each case reported in the literature, *P. crispus* reaches maximum biomass and senesces at lower water temperatures or earlier in the growing season for given regions (Table 2). This is especially noticeable where the two species occur together in the same community. *Potamogeton crispus* often senesces when water temperatures exceed 20°C.

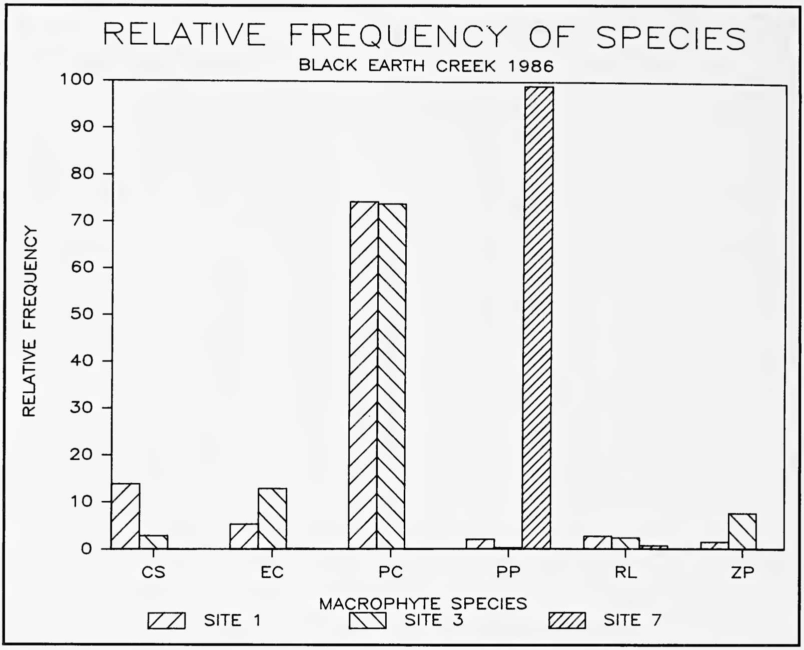

Fig. 6. Relative frequency of macrophyte species at sites 1, 3, and 7 in Black Earth Creek during 1986. Species codes: CS, Callitriche stagnalis*; EC,* Elodea canadensis*; PC,* Potamogeton crispus*; PP,* Potamogeton pectinatus*; RL,* Ranunculus longirostris*; ZP,* Zannichellia palustris.

Potamogeton pectinatus, on the other hand, is relatively insensitive to high temperature in the temperate zone and may form dense monocultures in streams with maximum daily temperatures above 23°C (Wong et al. 1978). In this respect, Badfish Creek and Black Earth Creek near Black Earth are similar in their thermal regimes. The longitudinal trend for warming downstream creates the conditions that promote a *P. pectinatus* monoculture at site 7.

Although the monthly maximum temperature at Black Earth is only 1–2°C higher than at Cross Plains, the critical temperature to initiate the senescence of *P. crispus* (approximately 20°C) is reached in May rather than late June (Fig. 7). Therefore, the phenologies of the two sites would be radically different. *Potamogeton crispus* theoretically would senesce much earlier at site 7 than sites 1 and 3, which may either mean that it was already senescent by the time that research began or its potential for success at site 7 is too poor for it to survive or compete against *P. pectinatus.*

Cover data from 1985 for sites 1 through 7 do not indicate a gradual transition from *P. crispus* to *P. pectinatus,* but rather a dramatic increase in *P. pectinatus* in site 7 from low relative percentages upstream. The relative percentage of *P. crispus* is also reduced in sites 5 and 6 from sites 1 through 4. We expect this is due to increased shading and lack of suitable substrates in sites 5 and 6, rather than to the observed temperature shift.

The effect of temperature was further in-

Table 2. Water temperature (°C) range or season of the year* for the growth and dominance of *Potamogeton crispus* and *P. pectinatus.*

Location	*P. crispus*	*P. pectinatus*	*Reference*
Otsego L., NY	max 21		6
Ojaga-ike, Japan	10–22		10
Collins L., NY	10–22		19
Pongolo R., SA	16–22		14
Bhagalpur, India	1–5*		15
L. St. Clair, MI	4–6*		18
Ltl. Conesus Cr, NY	max 5*		12
Japan	10–5*	4–7*	8
Halverson L., WI	4–7*	5–8*	4
Ramgarh L., India	8–6*	5–8*	16
Naini Tal, India	max 3*	max 5*	13
Jaipur, India	max 5–6*	max 6–7*	17
Ontario Rivers	max 19–22#	max 23+	20
Badfish Cr., WI		15–23	11
Eau Galle Res., WI		12–27	2, 5
Fox L., ND		16–28	9
Swartvlei, SA		16–28	7
L. Mendota, WI		5–7*	3
Delta Marsh, Man.		max 6*	1

* Month of the year rather than temperature (°C)

#Indicated as *Potamogeton* sp.

1, Anderson and Low 1976; 2, Barko et al. 1984; 3, Carpenter 1980; 4, Engel 1985; 5, Filbin and Barko 1985; 6, Harman 1974; 7, Howard-Williams 1978; 8, Kadono 1984; 9, Kollman and Wali 1976; 10, Kunii 1982; 11, Madsen 1986; 12, Peverly 1979; 13, Purohit and Singh 1985; 14, Rogers and Breen 1980; 15, Saha 1986; 16, Sahai and Sinha 1976; 17, Saxena 1986; 18, Schloesser et al. 1985; 19, Tobiessen and Snow 1984; 20, Wong et al 1978.

vestigated by examining the submersed macrophyte flora of streams in south-central Wisconsin, both from literature sources and by a one-time confirmatory visit to most of the ten streams (Table 3). Unfortunately, there is insufficient data on both the occurrence of *P. crispus* and *P. pectinatus* to draw any conclusions, other than that the two *Potamogeton* species are not the typical macrophyte species of the average south-central Wisconsin stream. Both sites with *P. crispus,* Black Earth Creek and Vermont Creek (a tributary to Black Earth Creek), are enriched by nonpoint source pollutants. The only stream other than Black Earth Creek and Badfish Creek to have *P. pectinatus* is Rutland Branch, where it only grows in the 100 m of that stream above its confluence with Badfish Creek. Therefore, these two *Potamogeton* species appear to be restricted to the most eutrophic streams in the area. In the absence of excessive cultural eutrophication, Black Earth and Badfish Creeks would probably have vegetation more typical for calcareous streams of the region, namely, *Elodea canadensis, Nasturtium officinale* (a semi-emergent macrophyte), *Ranunculus longirostris,* and *Veronica catenata.*

When sites from across Wisconsin tabulated from literature sources are examined, a distinct pattern emerges when comparing the four previously mentioned native, or mesotrophic, species and the two nonnative, eutrophic species (Table 4). *Potamogeton pectinatus* and *P. crispus* do indeed tend to be found in the most eutrophic of streams, while *Elodea, Nasturtium, Ranunculus, Veronica* are the predominant species of relatively clear, clean, cool streams. Because of its combination of species, both mesotrophic and eutrophic, Black Earth Creek appears to be transitional between the two, with a trend from mesotrophic in the headwaters to eutrophic near Black Earth. This trend is in

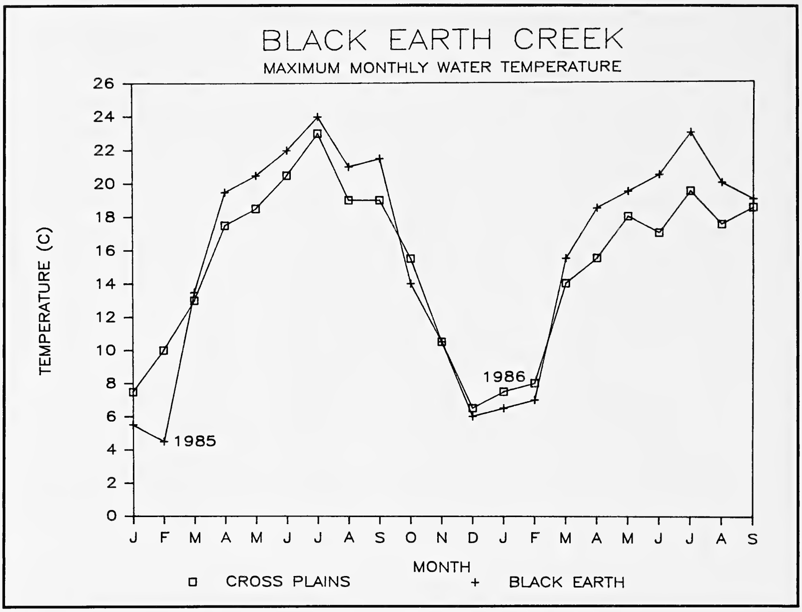

Fig. 7. Maximum monthly temperatures from 1985 through 1986 for Black Earth Creek at Cross Plains (site 2) and Black Earth (site 7). Data provided by Steve Field, U.S. Geological Survey.

large part due to the change in water temperature along its length but is also due to heavy nonpoint and point inputs of nutrients (Born 1986). Our conclusion of decreasing water quality in the downstream direction is substantiated by the Hilsenhoff Biotic Index on macroinvertebrate species for three separate years of collections (Born 1986).

A statistical analysis of the occurrence of these species throughout the state by the Fisher's Exact Test indicate some interesting ecological relationships *Elodea canadensis* was found to inhabit both mesotrophic and eutrophic streams with no partiality ($p = 0.25$). However, *N. officinale* ($p = 0.009$) and *R. longirostris* ($p = 0.0003$) occurred most commonly in mesotrophic streams. *Potamogeton crispus* ($p = 0.08$) and *P. pectinatus* ($p = 0.0009$) occurred significantly more often in eutrophic streams. However, this trend should not be construed as being a set of obligate "indicator species" for water quality, good or bad. *Nasturtium officinale* would best indicate cool, spring-fed streams, but not a range of nutrient concentrations. The occurrence of *P. pectinatus* does not necessarily indicate eutrophic conditions as it can occur in pristine, mesotrophic streams, especially those with sandy substrates. For instance, *P. pectinatus* is a common submersed macrophyte on sandy substrates in Lawrence Creek (Madsen 1982) and in the Bois Brule River (Thomas 1944), both very clean streams. However, *P. pectinatus* is a very common species in eutrophic streams throughout North America.

Conclusions

Total biomass at sites 1 and 7 was significantly lower in 1986 than 1985 but was similar for the two years at site 3. The difference

Table 3. Occurrence of submersed macrophyte species and maximum summer water temperature (°C) in south-central Wisconsin streams, and frequency* among the ten streams.

	Streams										
Species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Freq.**
Callitriche verna						X					1
Elodea canadensis	X	X		X	X	X			X	X	7
Nasturtium officinale		X	X	X	X	X	X		X	X	8
Potamogeton crispus						X		X			2
Potamogeton pectinatus	X			X		X					3
Potamogeton zosteriformis						X		X	X	X	4
Ranunculus longirostris		X		X		X	X	X	X		6
Veronica catenata				X	X	X		X	X	X	6
Zannichellia palustris				X	X	X			X		4
Maximum Water Temperature (C)	23	20	25	16	—	21	18	25	19	21	
References	1	4	4	1	1	1	2	6	1	6	
	4	6	6	4		to	6		4		
			8	6		7			6		
						9			7		

Streams: 1, Badfish Creek; 2, Frogpond Creek; 3, Oregon Branch; 4, Rutland Branch; 5, Spring Creek; 6, Black Earth Creek; 7, Garfoot Creek; 8, Vermont Creek; 9, Mount Vernon Creek; 10, Little Sugar River.

References: 1, This Study; 2, Born 1986; 3, Brynildson and Mason 1975; 4, *DCRPC* 1980; 5, Johnson 1969; 6, Lathrop and Johnson 1979; 7, Mace et al 1984; 8, Madison Metropolitan Sewerage District unpubl. data; 9, WDNR 1977.

between the two years' biomass is attributed to flood scouring, which greatly affected the sediments at sites 1 and 7, but not at site 3. Although total biomass is significantly different, species composition is consistent for the three years examined. For sites 1 and 3, *P. crispus* is dominant, with an assemblage of *C. stagnalis, E. canadensis, P. pectinatus, R. longirostris,* and *Z. palustris.* At site 7, a near-monoculture of *P. pectinatus* occurred with only a small percentage of *R. longirostris* as a marginal plant. This species shift is due to increased water temperature and eutrophication downstream. Seasonal succession patterns were also typical of previous years, with *P. crispus* as an early season dominant and *E. canadensis* and *P. pectinatus* as late season dominants. The two *Potamogeton* species are typical dominants of eutrophic streams, whereas native species, such as *Nasturtium* and *Ranunculus,* dominate in relatively unpolluted mesotrophic streams. Black Earth Creek is at the transition between a mesotrophic and eutrophic state, with water quality decreasing downstream. In general, historical factors, such as floods, may greatly alter total biomass for the current and following years but were not observed in this case to significantly alter species composition in the following year.

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Table 4. Occurrence of six macrophyte species common to either mesotrophic or eutrophic streams in Wisconsin, and p-value for a Fishers Exact Test.

Stream	*TS*	*EC*	*NO*	*RL*	*VC*	*PC*	*PP*	*Reference*
Ashippun R.	E						X	6
Badfish Cr.	E	X					X	8
Bark R.	E	X				X	X	6
Black Earth Cr.	E	X	X	X	X	X	X	1
Cedar Cr.	E						X	6
Milwaukee R.	E	X					X	6
Mukwonago R.	E	X					X	6
Pewaukee R.	E					X	X	6
Scuppernong R.	E	X						6
Beaver Cr.	M			X				3
Bois Brule R.	M	X		X			X	10
Emmons Cr.	M		X	X				4
Frogpond Cr.	M	X		X				1
Garfoot Cr.	M		X	X				1
Kinnikinnic R.	M	X		X				5
Lawrence Cr.	M	X	X	X	X		X	7
Ltl. Plover R.	M		X	X	X			5
Ltl. Sugar R.	M	X	X		X			1
McCann R.	M		X					5
Mecan R.	M		X	X				4
Mt. Vernon Cr.	M	X	X	X	X			6
Pine-Popple Rs	M	X		T			X	9
Radley Cr.	M		X	X				4
Rutland Br.	M	X	X	X	X		X	1
Seas Branch Cr.	M		X	X				2
Spring Cr.	M	X	X		X			1
Spring Cr.	M			X	X			5
Vermont Cr.	M			X	X	X		1
Wedde Cr.	M		X	X				3
Frequency:								
Eutrophic:	9	6	1	1	1	3	8	
Mesotrophic:	20	9	13	17	8	1	4	
Total	29	15	14	18	9	4	12	
Fisher's Test								
$p < 0.10$:			*	*		*	*	
$p < 0.01$:			*	*			*	

TS, Trophic Status (M, Mesotrophic; E, Eutrophic); EC, *Elodea canadensis*; NO, *Nasturtium officinale*; RL, *Ranunculus longirostris*; VC, *Veronica catenata*; PC, *Potamogeton crispus*; PP, *Pontamogeton pectinatus*.

References: 1, This Study (see Table 3); 2, Avery 1978; 3, Avery 1985; 4, Avery and Hunt 1981; 5, Hunt 1979; 6, Mace et al 1984; 7, Madsen 1982; 8, Madsen 1986; 9, Smith 1978; 10, Thomson 1944.

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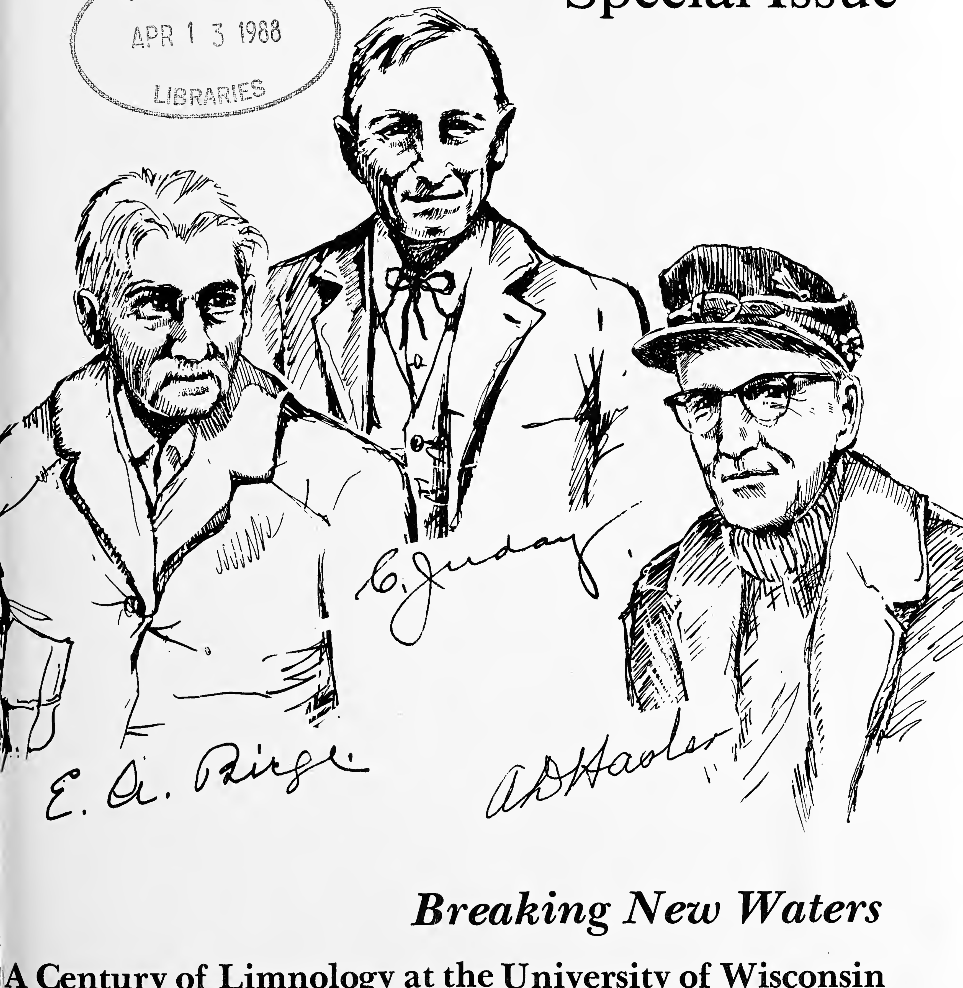

Breaking New Waters

A Century of Limnology at the University of Wisconsin

Transactions

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TRANSACTIONS

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Special Issue

Breaking New Waters

A Century of Limnology at the University of Wisconsin

Annamarie L. Beckel
with a contributing chapter
by Frank Egerton

From the Editor

It is with pleasure that the Wisconsin Academy of Sciences, Arts and Letters presents this Special Issue of *Transactions*. Limnology, at least as an organized study, had its infancy in Wisconsin, and much of the early research of the organizers (Juday, Birge, Hasler) was published in *Transactions*. These were men of strong commitment to scholarship and excellence in research, and their personal stamp has been indelibly made on limnology.

We at *Transactions* are happy to continue our ties with limnology and to be able to make the current study available. We think it will be of interest not only to Academy members but to people with special interests in limnology.

This publication was made possible by financial support from the University of Wisconsin Graduate School, the National Science Foundation (BSR 8514330), and the Center for Limnology Endowment Fund of the University of Wisconsin Foundation.

Carl N. Haywood

Contents

Foreword

History provides a context to help us understand the present and insights to help us shape the future. We welcome this history of two schools of limnology at a time when the insights that can come from it are of special value. This history project began soon after the formal establishment of the Center for Limnology on the Madison Campus in July 1982. This special issue of the *Transactions* constitutes a look back as Wisconsin limnologists continue the search to break new waters. In a less parochial context this book comes in the year that the 50th meeting of the American Society of Limnology and Oceanography (ASLO) was celebrated in Madison. The Society formed from the efforts of many limnologists, especially Paul Welch at the University of Michigan; ASLO and the collections of scientists it represents are halfway through their first century. Again, a look back can serve us well as we move ahead.

Chancey Juday, the first president of ASLO (then the Limnological Society of America) is one of the principals in this history. He, Edward A. Birge, and Arthur D. Hasler are portrayed on the cover and are catalysts of our history. We thank these limnologists and their many colleagues for a rich history of personal and scientific accomplishment. We thank Annamarie L. Beckel and Frank N. Egerton for preparing these excellent perspectives on two schools of Wisconsin limnology, and we thank the Wisconsin Academy of Sciences, Arts, and Letters for publishing these perspectives.

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Preface

The development of the science of limnology is inextricably entwined with the careers of Edward Asahel Birge and Chancey Juday, and later with that of Arthur Davis Hasler. The limnological research program at the University of Wisconsin-Madison has been one of the foremost in the nation. The research and ideas generated there have played a major role in shaping the growth and development of limnology in North America and abroad.

Scientific limnology began with the publication in 1895 of the first two volumes of Alphonse Forel's monograph, "Le Leman; monographie limnologique," which embraced geology, physics, and chemistry (Egerton 1983, Elster 1974). It was the partnership of Birge and Juday, however, that substantially laid the foundations of limnology in North America (Cole 1979, McIntosh 1977, Welch 1935). The work they and their associates performed during the first 40 years of this century marked the onset of modern American limnology and made conditions in Wisconsin lakes a touchstone for later studies in other regions (Cole 1979). Nearly 200 of the 400 scientific reports written by this group were published in the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters,* of which Birge was an active member. As noted by Frey (1963), a chronological listing of the papers and reports arising from their efforts closely parallels the general development of the science of limnology as reflected by changing rationale, methods of attack, and problems being investigated.

During their forty-year partnership Birge and Juday had chosen no successor to lead the Wisconsin limnological program. With the death of Juday in 1944 and the waning strength of Birge, research in limnology began to decline, and the Wisconsin school nearly went out of existence. Arthur Hasler, a former student of Juday, returned to the University of Wisconsin as an instructor in 1937. Although he seemed like a natural choice for the next leader of the Wisconsin program, neither Birge nor Juday gave him any help or encouragement in his own research endeavors, which were in an entirely different direction from theirs. Hasler turned away from the descriptive, comparative research conducted by Birge and Juday and established experimental limnology as the hallmark of the Wisconsin school. He was instrumental in reestablishing the reputation of the University of Wisconsin as a leader in limnological research.

Hasler retired from teaching and active research in 1978. He made the leadership transition much easier for his successor, John J. Magnuson, than Birge and Juday had for him. Under Magnuson's leadership, the Center for Limnology at the University of Wisconsin-Madison continues to be known internationally for its contributions to the science of limnology.

The purpose of this book is to chronicle the century of development in limnology at the University of Wisconsin-Madison, from Birge's arrival at the university in 1875 to Hasler's retirement from active research in 1978. The first four chapters take a much different approach than the last chapter written by Frank N. Egerton, an historian of science from the University of Wisconsin-Parkside. The first chapters tell the story of Wisconsin limnology from the perspective of the participants—Birge, Juday, Hasler, and their associates—the observers from the "inside." These chapters include relatively little analysis or evaluation of the participants' perspectives or memories—the limnologists themselves tell the story as they saw it. Egerton, on the other hand, considers the development of the Wisconsin limnological community from the analytical and technical perspective of a contemporary historian of science—the observer from the "outside." The main focus of Egerton's discussion is on the contrasting development of the Wisconsin program under the leadership first of Birge and Juday and then of Hasler. He discusses the similarities and differences in outlook, goals, methodologies, and major achievements of the two programs and, in some cases, arrives at different conclusions than the limnologists themselves.

The major sources of information for the first four chapters include interviews and discussions with former students and colleagues of Birge, Juday, and Hasler, as well as interviews with Hasler. Most of these interviews were conducted at a conference, "History of Limnology in Wisconsin," held in May 1983 at the University of Wisconsin Trout Lake Station in northern Wisconsin. Many former students and colleagues who could not attend the conference contributed written interviews. Transcripts of taped interviews, written interviews, and questionnaires are catalogued in the University of Wisconsin archives. I made extensive use of G. C. Sellery's biography of Birge (1956), including C. H. Mortimer's chapter, "An Explorer of Lakes," in which Mortimer evaluates the scientific contributions of Birge. I also acknowledge my debt to David G. Frey and Arthur Hasler for their chapters in *Limnology in North America* (Frey 1963). Additional sources of information included the Birge Collection in the State Historical Society of Wisconsin, correspondence between Juday and two of his students, Stillman Wright and Robert W. Pennak, and the technical publications of Birge, Juday, and Hasler. For his chapter, Egerton conducted extensive interviews with Hasler, but Egerton's analysis of the achievements of the Birge-Juday program and the Hasler program relies on written records and the documented contributions of the Wisconsin school to limnology.

This book is not meant to be a biography of any of the principal players, but Egerton and I do hope to present a picture of how individual personalities can shape the growth and development of a scientific community. There are certainly some major differences in the ways that Birge and Juday and Hasler envisioned their research programs and in the ways they dealt with colleagues, graduate students, funding agencies, and the public that influenced how the Wisconsin program developed.

In the book we have discussed some of the major contributions of the Wisconsin program to limnology. More than 100 limnology related master's and doctoral theses, as well as nearly 800 other publications, were produced by Birge, Juday, Hasler, and their associates between 1875 and 1978. Certainly not all these studies are discussed in detail. Complete lists of the graduate students of Juday and Hasler are included in the appendix. Lists of the publications of Birge and Juday and their students and associates and of Hasler and his students and associates can be obtained from the Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, Wisconsin 53706. For additional discussion of these research projects see the chapters written by Frey and Hasler in *Limnology in North America* (Frey 1963).

Annamarie L. Beckel
University of Wisconsin, 1987

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Acknowledgments

We would like to thank all the participants in the "History of Limnology in Wisconsin" conference held in May, 1983, at the University of Wisconsin Trout Lake Station. We would also like to thank all of those who agreed to be interviewed or who took the time to fill out questionnaires regarding their experiences in the Wisconsin limnological program. The list of conference participants and those who were interviewed or filled out questionnaires is as follows:

John E. Bardach (Ph.D. 1949) was a student of Hasler. His thesis research was on the population dynamics and life history of yellow perch in Lake Mendota. He is officially retired, but continues to hold appointments and to work as adjunct research associate at the East-West Resource Systems Institute at the East-West Center in Honolulu, Hawaii, and in the Departments of Oceanography and Geography at the University of Hawaii.

George C. Becker was a student of Hasler (M.S. 1951) and of John Neess (Ph.D. 1962). Since 1951 he has been conducting research on the fish in the lakes and streams of Wisconsin. He is currently living in Rogers, Arkansas, having retired as Emeritus Professor of Biology and Curator of Fishes at the University of Wisconsin-Stevens Point.

W. A. Broughton was a student of geologist W. H. Twenhofel and also received advice from E. F. Bean, the State Geologist. During the summers of 1937 and 1939 he conducted research on the sediments of Crystal Lake and a number of other lakes and bogs in the Trout Lake area. He is currently living in Plattville, Wisconsin, having retired as the Chairman of the Geology Department at the University of Wisconsin-Plattville.

George L. Clarke was a visiting scientist from the Woods Hole Oceanographic Institute in the summer of 1939 when he worked with Birge and Juday at the Trout Lake Station. There he conducted research on the transparency of lake water and perfected the Clarke-Bumpus plankton sampler. He is currently living in Belmont, Massachusetts.

Faye M. Couey (M.S. 1932) was a student of endocrinologist Frederick Hisaw and parasitologist Chester A. Herrick. In 1931 and 1932 he conducted fish food studies at the Trout Lake Station. He is now living in Kalispell, Montana, having retired from the Montana Fish and Game Department.

Herbert J. Dutton (Ph.D. 1940) was a student of physical chemist Winston Manning and plant physiologist Benjamin Duggar. In the summer of 1940 he had a postdoctoral appointment to work on chromatic adaptation in relation to color and depth distribution of freshwater phytoplankton and large aquatic plants in the Trout Lake region. In 1980 he retired as Chief of the USDA's Oilseed Crops Laboratory, Northern Regional Research Center, Peoria, Illinois, and was subsequently appointed Honorary Fellow, University of Minnesota at the Hormel Institute. He now shares research time between that institution, the Trout Lake Station, and his home on Diamond Lake in Cable, Wisconsin.

W. T. Edmondson, Ph.D., was a student of G. E. Hutchinson at Yale University. He spent the year 1938–1939 studying limnology and doing research at the University of Wisconsin-Madison and at the Trout Lake Station under the sponsorship of Juday. He is now Professor Emeritus of Zoology at the University of Washington in Seattle.

Daniel J. Faber (Ph.D. 1963) was a student of Hasler. His thesis research was on limnetic larval fish in several northern Wisconsin lakes. He is currently a Senior Scientist at the National Museum of Natural Sciences in Ottawa, Ontario.

David G. Frey (Ph.D. 1940) was the last student of Juday. As an undergraduate he worked as an assistant to William Spoor, who was also Juday's student, and to Juday at the Trout Lake Station in 1934. His thesis research was on the growth and ecology of carp in Madison lakes. He is currently Professor Emeritus in the Department of Biology at Indiana University in Bloomington.

Bradford C. Hafford (Ph.D. 1942) was a student of V. W. Meloche, working on techniques for analyzing the chemistry of lake waters. He worked as a chemistry assistant at the Trout Lake Station in 1939 and 1940. He became involved in pollution abatement research in his industrial career and retired as Vice President of Research and Development for the Natural Resources Group of Gulf and Western Industries. He currently lives in Hawley, Pennsylvania.

Donald L. Halverson (M.S. 1918) was a member of the instructional staff and then Director of Residence Halls for 22 years at the University of Wisconsin where he came to know Birge when he was Dean and later, University President, and Juday when he was Professor of Limnology. During the summers of the years Birge and Juday were at the Trout Lake Station, Halverson saw them almost daily as they were close neighbors on the Trout Lake Point. In later years, Halverson and Hasler became close friends. Halverson retired from the university as a Professor of housing. He died September 6, 1987.

William T. Helm (Ph.D. 1958) was a student of Hasler and John Neess. He worked on the population dynamics of young walleye in stocked and unstocked lakes, the effects of alkalization and fertilization in Cather Lake , and, for his doctoral thesis, the ecology of fishes in Lake Wingra. He is currently in the Department of Fisheries and Wildlife at Utah State University in Logan.

John R. Hunter (Ph.D. 1962) was a student of Hasler, working on the net avoidance behavior and reproductive behavior of fishes in both laboratory and field studies. He is currently with the U.S. National Marine Fisheries Service, Southwest Fisheries Center in La Jolla, California.

Richard E. Juday (Ph.D. 1943) is the son of Chancey Juday. He worked as an assistant to "Dad's scientists" at the Trout Lake Station from 1934 to 1940. He completed an undergraduate degree at Harvard University and returned to the University of Wisconsin for a doctorate in organic chemistry. He has recently retired from the Chemistry Department at the University of Montana in Missoula.

Charles M. Kirkpatrick (Ph.D. 1943) was a student of physiologist R. K. Meier and wildlife ecologist Aldo Leopold, working on the endocrinological development of Ring-necked Pheasants. In the summers of 1939 and 1940 he worked as an assistant to Juday and to botanist John Potzger at the Trout Lake Station, where he also conducted independent research on the foods of young Great Blue Herons. He is now Emeritus Professor in Wildlife Ecology in the Department of Forestry and Natural Resources at Purdue University in West Lafayette, Indiana.

Gail Kirkpatrick accompanied her husband to the Trout Lake Station in the summer of 1940. She was paid $50 plus her food and lodging for the summer to work as the cook for about ten of the scientists and graduate students.

E. David Le Cren (M.S. 1947) was a student of Hasler, working on perch population ecology in Lake Mendota. He has recently retired as Director of the Freshwater Biological Association at the Windermere Laboratory in England.

John J. Magnuson joined the Zoology Department at the University of Wisconsin-Madison in 1968. He had completed a Ph.D. in 1961 at the University of British Columbia and had worked on the behavior and physiology of tuna in Hawaii for seven years before coming to Wisconsin. He is currently Director for the Center for Limnology at the University of Wisconsin-Madison.

Villiers W. Meloche was the chief chemist for Birge and Juday at the Trout Lake Station following George Kemmerer's death in 1928. He was known as a pioneer in developing new techniques for the chemical analysis of lake water. He was interviewed in 1979 about his experiences at Trout Lake. Meloche died in 1981.

John C. Neess (Ph.D. 1949) was a student of Hasler. His thesis research on the population ecology of bluntnose minnows was conducted in artificial ponds in the University of Wisconsin Arboretum. He joined the Department of Zoology at the University of Wisconsin-Madison shortly after completing his degree. Over the years he advised a number of Hasler's students on problems in experimental design and statistical analysis.

Robert W. Pennak (Ph.D. 1938) was a student of Juday. He worked as an assistant to Juday at the Madison campus from 1934 to 1936 and at the Trout Lake Station during the summers of 1935 through 1938 while he did his own thesis research on the ecology of psammolittoral organisms (beach interstitial faunas). He is currently Professor Emeritus in the Department of Environmental, Population, and Organismic Biology at the University of Colorado in Boulder.

John J. Peterka (M.S. 1960) was a student of Hasler, working on the survival of trout in bog lakes in northern Wisconsin. He is currently in the Department of Zoology at North Dakota State University in Fargo.

Gerald Prescott was a visiting scientist from Albion College and later, from Michigan State University when he worked at the Trout Lake Station in the summers of 1936 through 1938. He conducted research on the taxonomy and distribution of algae in relation to the chemistry of lake waters. He is currently Emeritus Professor of Botany at Michigan State University in East Lansing and at the University of Montana in Missoula, but resides in Wyoming, New York.

Robert A. Ragotzkie (Ph.D. 1953) was a student of Hasler and Reid A. Bryson, conducting research on the physical limnology, zooplankton, and heat budgets of lakes. He is currently Director of the Sea Grant Institute at the University of Wisconsin-Madison.

Rex J. Robinson (Ph.D. 1929) was a student of analytical chemist George Kemmerer, working on methods for the chemical analysis of lake water. He worked as an assistant to Birge and Juday at the Trout Lake Station in the summers of 1926 through 1929. From 1929 through 1971 he was a member of the Chemistry Department at the University of Washington in Seattle. From 1931 to 1955 he was also a member of the Oceanographic Laboratories at the University of Washington. Robinson retired in 1971 as Emeritus Professor of Chemistry and now lives in Seattle.

Clarence L. Schloemer (Ph.D. 1939) was a student of Juday, but also received advice from Ralph Hile, who was working for the U.S. Bureau of Fisheries when he worked with Birge and Juday at Trout Lake. Schloemer conducted research on the age and rate of growth of bluegill and also worked on the growth of game fish, such as muskellunge and walleyes, in northern Wisconsin lakes. He is currently Professor Emeritus at Michigan State University in East Lansing.

William R. Schmitz (Ph.D. 1958) was a student of Hasler. For his thesis research, he studied winterkill conditions in northern Wisconsin lakes. He was Associate Director for the Trout Lake Station from 1966–1977, and is currently in the Department of Biological Sciences at the University of Wisconsin-Marathon campus.

Edward Schneberger (Ph.D. 1933) was a student of Juday, but also received advice from fisheries biologist Ralph Hile. He conducted research on the bottom fauna of lakes and also on the distribution, ecology, age, and growth of fishes in northern Wisconsin lakes. His thesis research was on the growth of yellow perch in three lakes in the Trout Lake region. Shortly after graduation, he was employed by the Wisconsin Conservation Department, now the Wisconsin Department of Natural Resources. He served as Fisheries Biologist, Superintendent of Fish Management, and Director of Research and Planning. He has retired from the Wisconsin Department of Natural Resources, and he and his wife, Helen, now live in Middleton, Wisconsin.

Helen Schneberger accompanied her husband to the Trout Lake Station during the summers of 1930–1934. In 1932 she was hired to be the cook for the scientists and students at the station.

Fredrick J. Stare, Ph.D., M.D., was a student of C. A. Elvehjem. He was an undergraduate when he worked at the Trout Lake Station as a chemistry assistant to V. W. Meloche in the summers of 1928 through 1931. He founded the Department of Nutrition at Harvard University in 1942 and is currently Professor Emeritus of Nutrition in the Harvard University School of Public Health in Boston, Massachusetts.

Raymond G. Stross (Ph.D. 1958) was a student of Hasler and advisee of John Neess. He continued the experimental lake liming project on Peter-Paul lakes. The research focused on retention of the lime and its effect on water transparency, iron, and phosphorus retention, and on zooplankton production. His study was the first to estimate turnover times in wild *Daphnia* populations. He also studied predator substitution in a fishless lake. He is currently in the Department of Biological Sciences at the State University of New York at Albany.

Dale Toetz, Ph.D., was an undergraduate assistant to Hasler's students, Daniel Faber and William Helm, in 1958 when they were conducting research on walleye year-class strength. He was also a student of John Neess (M.S. 1961) and later received a Ph.D. (1965) from Indiana University. He is currently Professor of Zoology at Oklahoma State University in Stillwater.

Clyde W. Voigtlander (Ph.D. 1971) was a student of Hasler. For his thesis research he worked on the biology of white bass in Lake Mendota. He is currently with the Environmental Quality Staff of the Tennessee Valley Authority in Knoxville.

Leonard R. Wilson (Ph.D. 1935) was a student of botanist Norman Fassett and geologist Frederick Thwaites. In the summers of 1932 through 1934 he worked at the Trout Lake Station as an assistant to Birge and Juday, and in 1936, as a visiting scientist from Coe College in Iowa. He conducted research on vegetation types, abundance, and succession in northern lakes. He is currently George L. Cross Research Professor of Geology and Geophysics, Emeritus, and Curator of Micropaleontology and Paleobotany at the Museum of Science and History at the University of Oklahoma in Norman.

Warren J. Wisby (Ph.D. 1952) was a student of Hasler. He conducted both laboratory work and field research on homing in salmon. Wisby also studied homing in black bass. He is currently Associate Dean of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami in Florida.

Thomas E. Wissing (Ph.D. 1969) was a student of Hasler. His thesis research was concerned with the ecological energetics of young-of-the-year white bass in Lake Mendota. He is currently Professor of Zoology at Miami University in Oxford, Ohio.

Stillman Wright (Ph.D. 1928) was a student of Juday, conducting research on zooplankton in Madison lakes and in South America. The summers of 1925 and 1927 he was employed by the U.S. Bureau of Fisheries as an assistant to Juday in investigations of northern lakes. Wright began working for the U.S. Bureau of Fisheries in 1938 and retired from the Office of Foreign Activites of the Bureau in March 1963. He currently resides in Chapel Hill, North Carolina.

Claude E. ZoBell was a visiting scientist from Scripps Institution of Oceanography when, as a Postdoctoral Fellow at the University of Wisconsin from September 1938 through May 1939, he studied the role of bacteria in lake metabolism. Janice Stadler, who was subsidized by the Works Progress Administration, was his full-time research assistant at the University of Wisconsin. ZoBell is currently Professor Emeritus of Marine Microbiology at the Scripps Institution of Oceanography, University of California, San Diego, La Jolla.

We would like to thank those people who helped conduct interviews: Carl Bowser, Department of Geology and Geophysics; Thomas Frost, Associate Director for the Trout Lake Station, Center for Limnology; and Jean Lang, University-Industry Research Program. We also appreciate the advice and comments of Art Spingarn, Botany Department, William Coleman, History of Science Department, Thomas Brock, Department of Bacteriology, Timothy Kratz, Center for Limnology, Robert McIntosh, Department of Biological Sciences, University of Notre Dame, W. T. Edmondson, Department of Zoology, University of Washington, and Katherine Webster, Wisconsin Department of Natural Resources, who reviewed early manuscripts of the book. The cooperation of the State Historical Society of Wisconsin in providing photographs for the book is also greatly appreciated.

1 Beginnings

Limnology at the University of Wisconsin began with the research of Edward A. Birge, who arrived in Madison in 1875 as an instructor of natural history at the university. Birge had begun studying Cladocera, a group of zooplankton, while he was a student at Williams College in Massachusetts. He continued research on the systematics of Cladocera at his new university post, but it was not until more than 20 years later, when Birge became interested in the physical and chemical conditions controlling the seasonal distribution of zooplankton in Lake Mendota, that his research became limnological.

About the turn of the century when Birge's research interests were turning toward limnology, he acquired a partner—a young limnologist from Indiana named Chancey Juday. The story of limnology in Wisconsin from 1900 to 1940 is the story of this famous partnership.

Birge was born in 1851 and grew up on a farm near New Haven, New York. He received A.B. (1873) and A.M. (1876) degrees from Williams College in Massachusetts. In the fall of 1873 Birge went to the Museum of Comparative Zoology in Cambridge to work with Louis Agassiz, probably the most well-known geologist and biologist in the country at that time.

> "Agassiz had all of the large collection of sea-urchins in the Museum brought out and placed on long tables in one of the corridors. I was to work them over, arrange and reclassify them, a task which would have occupied me for a couple of years or more. Agassiz visited me daily, asked about my progress, advised me as to books, etc. I suppose that if he had lived I should now be a specialist on the group of Echinodermata."
>
> E. A. Birge, 1936, "A House Half Built," an address to the Madison Literary Club.

Agassiz died only three months after Birge arrived, but Birge was given the opportunity to continue his education at Harvard, which was then organizing a graduate school (Sellery 1956). In 1875, before he had completed his doctoral degree, Birge left Harvard for Wisconsin.

At the time Birge arrived at the University of Wisconsin the school was only 25 years old and had only four to five hundred students. Birge was the first trained zoologist at the university, despite the fact that the 1870–1871 course catalog lists zoology as a department equipped for graduate work (Noland 1950). He constituted a one-man biology department, teaching courses in zoology, botany, bacteriology, human anatomy, and physiology (Frey 1963). After only four years as an instructor, including time off to complete a Ph.D. at Harvard in 1878, Birge was promoted to professor.

Birge played a major role in developing a research program in zoology and physiology at the University of Wisconsin. Before his arrival, there had been almost no biological research conducted at the university nor were there facilities or equipment for doing so. An 1850 inventory of the university library listed only one book on zoology, two on conchology, two on natural history, two on chemistry, 11 on medicine, and 62 on theology (Noland 1950).

Birge was among the first to emphasize individual laboratory work by students as a method of teaching. Although he initiated research courses for students, Birge found little time for his own research on Cladocera.

> "It is significant of the state which the University had then reached [1880] that no thought entered my head, or that of anyone else, that I should apply part of this time in research. Nor was there any thought of developing zoological teaching to the stage of graduate and professional courses. I decided to offer advanced undergraduate courses which should give a better scientific training to future students of medicine. . . . This teaching fully occupied my time for a decade, 1881–1891, and during those years there was little or no work on lakes. . . . During those years my interest in lakes and their inhabitants was not dead but was dormant."
>
> E. A. Birge, 1936, "A House Half Built."

Birge's first attempts at research were concerned primarily with the anatomy and systematics of Cladocera and were not really limnological. He has started studying *Daphnia* at Williams College and had continued his research at Harvard.

> "When the time came for a thesis *Daphnia* came to the fore again. I used my study of its anatomy and I worked up the group of microcrustacea to which it belongs as represented in Fresh Pond at Cambridge and later at Madison, especially in Lake Wingra. The resulting thesis was a very poor one, judged by any modern standards, even the most charitable, but it was the first attempt in this country to give a systematic account of the group of crustacea."
>
> E. A. Birge, 1936, "A House Half Built."

He became an authority on the taxonomy and ecology of Cladocera, as was recognized later when he was asked to write a chapter on Cladocera for H. B. Ward and G. C. Whipple's *Freshwater Biology* (1918). Prior to that monograph, Birge had written just four major papers dealing with the systematics of Cladocera, (1879, 1892, 1893, 1910b).

About the turn of the century his research took a distinct limnological turn, not so much by design as by accident. Birge had encountered a short paper by France' (1894) on diel migration, which demonstrated that in Lake Balaton in Hungary, the zooplankton come to the surface at night and do not descend to greater depths until about dawn, where they remain until early afternoon (Frey 1963). Birge was interested in determining how extensive the migration might be in Lake Mendota, a deeper lake than Balaton. To sample discrete water depths, he designed a vertical tow net that could be opened at any depth by means of a messenger and then closed again by a second messenger after pulling the net through a desired thickness of water (Frey 1963). Birge and his two senior thesis students, O. A. Olson and H. P. Harder, collected microcrustacea from different depths and counted the numbers of each species. This procedure was repeated every three hours, day and night, for several groups of days in July and August and also later in the year. When they had counted the crustacea in all the catches, they found no evidence of vertical migration at dusk or dawn, but Birge and his students did find an unexpected vertical distribution of the plankton.

> "No one could have had limnology less in mind than I did when in 1894 I started to work out, by quantitative methods, the annual story of the microcrustacea of Lake Mendota . . . for the best authority tells us that the word limnology did not appear in English until more than a year after our work began. . . .
>
> "I meant to make a thorough study, so I selected a primary station about half way out to Picnic Point, where the water is about sixty feet deep. This depth was to be divided into six levels of ten feet each; the crustacea were to be collected separately from each level, and the different

species determined and counted. This process was to be continued for a year or more. In fact, it went on until the end of the year 1897, and included from the several depths nearly five thousand catches, each containing up to a dozen forms of crustacea, of which eight species were abundant. . . .

"May I not venture just a hint that, when a monument seems to suit my condition better than a dinner, a spar-buoy properly painted and firmly anchored there [end of Picnic Point] would suitably commemorate my transfer from zoology to limnology.

"In the early days of this study, Mendota surprised me by a revelation of a peculiarity in her life as a lake which was to determine my thinking and my work in science for all the following years. As our crustacea-catching continued into midsummer we found that our booty began to disappear from the lower waters of the lake. The process continued until the lake became divided into two widely different parts. There was an upper lake, about 30 feet thick, whose water was warm and was filled with abundant plant and animal life. Below this lay an abrupt transition to the lower and colder half of the lake, which was not only cold but also without living plants and animals. . . .

"As Mendota cooled in autumn its upper and active stratum gradually became thicker and the lake reached its full activity at all depths in late October or early November, an activity limited only by the lower temperature of the water. This process is repeated every year.

"This story, which Mendota told me without my asking for it was the revelation that sent me into limnology."

E. A. Birge, 1940, First Symposium on Hydrobiology, held in Madison on Birge's 89th birthday to honor him for his contributions to limnology.

In these studies of zooplankton in Lake Mendota, Birge became more and more intrigued with the physical and chemical conditions controlling the distribution of the crustacea. Research on the seasonal distribution of plankton led him directly into an investigation of thermal stratification and lake chemistry.

These early studies of plankton distribution in Lake Mendota (Birge, Olson, and Harder 1895, Birge 1897) marked the beginning of limnology at the University of Wisconsin and of Birge as a limnologist (Frey 1963, Mortimer 1956). In these reports Birge not only described the seasonal and vertical distribution of eleven species of crustaceans, he also documented the story of the lake's seasons of circulation and stratification. It was not the first presentation of the annual temperature cycle in a lake, but Birge's interpretation of it in terms of the interplay of sun and wind has become classic (Mortimer 1956). In a paper on the annual thermal regime of Lake Mendota (Birge 1898), he noted many phenomena that are now part of our general understanding of the thermal dynamics of lakes—the lowering of the thermocline during summer, the increase in water temperature beneath the ice, the marked rise in temperature of the bottom water during the destruction of thermal stratification in autumn, and the variations in position and thickness of the thermocline under various wind stresses (Frey 1963). In this report, Birge introduced the word "thermocline" to limnology and oceanography. He introduced "epilimnion" and "hypolimnion" in a later paper on temperature seiches (Birge 1910a).

About the same time that Birge was completing his first plankton studies on Lake Mendota, the Wisconsin legislature established the Wisconsin Geological and Natural History Survey. The Wisconsin Academy of Sciences, Arts, and Letters, of which Birge was an active member, had played an instrumental role in the creation of the Survey. In 1893, the Academy had established a committee composed of Chairman C. R. Van

Hise, Birge, C. R. Barnes, G. L. Collie, and A. J. Rogers, to draw up a bill for presentation to the state legislature (Bean 1937). The legislature, however, was reluctant to consider the bill.

> "In 1873 the Wisconsin legislature commissioned what has come to be known as the [Thomas C.] Chamberlin Survey, which resulted in four volumes on the geology of Wisconsin, the last published in 1882. The legislature incorrectly thought that once a survey was done, it was done, there was no need to do another.
>
> "University scientists, however, agitated for a permanent survey. In 1893 the Wisconsin Academy of Sciences, Arts and Letters appointed a committee, led by geologist Charles Van Hise, to put together a proposal for a bill to establish a permanent survey. The bill was finally approved in the 1897 session."
>
> M. E. Ostrom, Director and State Geologist of the Wisconsin Geological and Natural History Survey, 1987, personal communication.

The legislature allocated $5000 a year for the Survey and appointed Birge as the Director (Bean 1937). He now had at his disposal considerably greater resources for conducting research. He found, however, that he had little time for research. Birge was not only Director of the Survey, but also Chairman of the Zoology Department (1875–1906), Dean of the College of Letters and Science (1891–1918), and Commissioner of Fisheries (1895–1915) for the state of Wisconsin. And in 1900 he was appointed Acting President of the University of Wisconsin, a position he held until 1903 (Frey 1963, Noland 1950). To keep his research program from suffering he began to look for a partner. He found Chancey Juday, whom he hired as Biologist for the Survey in 1900.

> ". . . the founding of the Survey in 1897 is an all important fact. . . . Looked at in the large, the story from this time on is a new one. . . . The most important result in the end was that it made possible the presence and work of Dr. Juday. . . . He was the first and for years the only limnologist in the country, and we knew the fact though we did not discover the word for a good many years."
>
> E. A. Birge, 1936, "A House Half Built."

Chancey Juday was born in 1871 in Millersburg along the northern edge of the lake district in Indiana. He received his A.B. (1896) and A.M. (1897) degrees from Indiana University where he met Carl Eigenmann, who in 1895 had established a biological station on Turkey Lake (currently Lake Wawasee) only a few miles from Juday's home (Frey 1963). It may have been through Birge's contacts with Eigenmann that Birge learned of the young limnologist who had studied plankton in Turkey Lake (Juday 1897), Lake Maxinkuckee (Juday 1902), and Winona Lake (Juday 1903). In Lake Maxinkuckee Juday had also studied the diurnal movements of plankton.

Juday's first assignment as Survey Biologist was to study diel migration of zooplankton in Mendota and other lakes of southeastern Wisconsin (Frey 1963). After only a year with the Survey, however, Juday developed tuberculosis and had to leave the Midwest. For the next few years, while he served on the biology or zoology staffs of the Universities of Colorado and California, there was a hiatus in limnology at the University of Wisconsin (Frey 1963, Noland 1945).

Juday rejoined the Survey in 1905 and was made a half-time lecturer in Limnology in the Department of Zoology at the University of Wisconsin in 1908. In 1909 he began teaching the first courses offered at the university in limnology and plankton organisms.

From October 1907 to June 1908 Juday travelled in Europe, visiting universities and biological stations in Germany, Denmark, Sweden, Austria, Hungary, Italy, France, and England, where he became acquainted with the leading aquatic biologists of Europe (Juday 1910). In February 1910 Juday travelled to Central America to study four semi-tropical lakes in Guatemala and El Salvador. As a result of his research there, he published one of the first studies in tropical limnology (Juday 1915).

Birge and Juday's early efforts as a team were concentrated on the Madison lakes, especially Mendota, and on other lakes in southeastern Wisconsin. Although their first joint paper was published in 1908, Birge and Juday's first major effort came in 1911 when they published the now classic paper on dissolved gases, "The inland lakes of Wisconsin: The dissolved gases of the water and their biological significance." The dissolved gases study had evolved directly from Birge's research on the seasonal distribution of microcrustacea in Lake Mendota.

> "It was an obvious guess that exhaustion of oxygen was at least one of the factors at work in summer, in the deeper water of Lake Mendota, to exclude the higher life of the lake from that region. So in 1904 there began the serious study of the dissolved gases of the lake water. Along with this there necessarily went careful observations of temperature; a little was done with light; much was done on conditions and changes in the minute life of the waters as affected by dissolved gases. The center of this activity was chemical and, therefore, with this study began that cooperation in our work of various University departments; out of this cooperation has come much of its success.
>
> "To this investigation Dr. Victor Lehner gave his time and energy without stint; he devised apparatus and methods; he directed the earlier work in person; then he initiated Dr. R. C. Benner as his successor."
>
> E. A. Birge, 1936, "A House Half Built."

During the five-year study a tremendous amount of information on water chemistry, temperatures, and plankton was accumulated from 156 lakes, mainly in southeastern Wisconsin, although many lakes in the northeastern and northwestern lake districts were examined briefly (Birge and Juday 1911). The 259-page report showed how seasonal changes in the distribution of dissolved gases are geared to the annual cycle of circulation and stratification and to the activities of plants, animals, and bacteria.

> "Judged by its influence on the subsequent development of limnology, the dissolved-gases report is the most outstanding single contribution of the Wisconsin school. In the remarkable introductory essay . . . Birge charts those regions of the lake environment which he had so largely helped to explore, and outlines some problems lying ahead. Holding within its many subsidiary ones, was the main problem: 'Why do lakes differ so widely in productivity or in ability to support a population of plankton?' This was a puzzle destined to occupy Birge and Juday for the rest of their lives, and one to which limnologists are still striving to find the solution."
>
> C. Mortimer, 1956, "An Explorer of Lakes."

In the 1911 dissolved gases study Birge and Juday established two traditions that were to continue throughout the course of their partnership and were to become trademarks of their work. The first tradition was a multidisciplinary approach to limnological research; the second was the collection of tremendous amounts of data. Birge and Juday recognized limnology as a synthetic science. Collaboration with scientists from other disciplines reached its height during later years when Birge and Juday were conducting research in Wisconsin's northeastern lake district. Many of these collaborators are discussed by Frank Egerton in chapter five.

> "The title pages of most of these reports carry the names of more than one author, and the list of such collaborators exceeds 50. The number is far greater of those who have helped bring together the data for these reports but who took no part in writing them. I emphasize the large number of collaborators, for the study of lakes is a synthetic science. . . . The biologist alone is quite helpless if he attempts to determine the laws governing the production of fish in a lake. He must ask help from the chemist, physicist, geographer, geologist, and meteorologist if he is to understand these laws or even appreciate their presence and estimate their influence."
>
> E. A. Birge, 1936, "A House Half Built."

> "A good many European limnologists used to talk about the broad base of limnology. Theinemann, Ruttner, Wolterek, and some of the other major European limnologists would stress the fact that limnology consisted of chemistry, plankton, bottom fauna, geology, microbiology, physics, rooted aquatics, and so forth. But these other people never gave it more than lip service. For the first time, Birge and Juday synthesized and realized as Birge put it, 'in order to find out how a lake keeps house, you've got to study all of these various aspects of the lake.' In my own view, they were really the first group in the world to put into being the idea that limnology is a synthesis of many different kinds of sciences."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

The second tradition, collecting a wealth of data, was based on Birge and Juday's belief that if enough data are gathered, the data will speak for themselves. They both thought that theorizing on the basis of too few data could be dangerous, and they shared a disdain for "desk-produced" papers.

> "As our work has progressed we have been increasingly impressed by the complexity of the questions involved. This has become more and more manifest as our experience has extended to numerous lakes and to many seasons. If this report had been written at the close of the first or second year's work, it would have been much more definite in its conclusions and explanations than is now the case. The extension of our acquaintance with the lakes has been fatal to many interesting and at one time promising theories."
>
> E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

Martin Gillen, a long-time friend and former student of Birge's, related this story:

> "I asked him [Birge] one evening, 'How many tests have you made with your "light machine" in the northern lakes?' He said, '19,952.' I replied, 'Well, Doctor, it will not be very long now before you will be able to announce a solution of this problem.' He stopped a moment, shook his head, and said, 'Martin, I think after this work is kept up twenty-five or thirty years longer, we may have the answer to it all.' "
>
> M. Gillen, 1940, First Symposium on Hydrobiology.

Birge and Juday were field limnologists and were somewhat skeptical of the value of laboratory experiments.

> "I suspect that [G. Evelyn] Hutchinson's conclusions regarding the killing of Cladocera by the zinc in Bear Lake was like a good many other conclusions derived from laboratory experiments;

> they are not valid in nature. Limnologists still have a lot to learn about plants and animals in their natural environment."
>
> C. Juday, 1940, letter to S. Wright.

Birge was attracted to the complexity of lakes and the then fashionable concept of a lake as a closed system, a microcosm or a "unit of environment," an individual with physiological processes analogous to those of an organism (Frey 1963, Mortimer 1956). No doubt both Birge and Juday were influenced by Stephen A. Forbes classic paper (1887) on the lake as a microcosm. The concept of the lake as a "unit of higher order" became a guiding principle in their work.

> "Perhaps the chief interest which our work has had for us has been the fact that its progress has revealed to us the existence of physiological processes in lakes as complex, as distinct, and as varied as those of one of the higher animals. . . . These are examples of questions whose solution demands not merely a knowledge of the biology of the several species of algae, but also the study of the several lakes as physiological individuals of a higher order."
>
> E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

> "The lake is the one true microcosm, for nowhere else is the life of the great world, in all of its intricacies, so clearly disclosed to us as in the tiny model offered by the inland lake."
>
> E. A. Birge, 1936, "A House Half Built."

As indicated in the dissolved gases report, Birge and Juday were aware of the rapid changes occurring in the young science—that limnology was evolving from the "natural history" phase toward being a true science.

> "Various papers which have been recently published on the problems of limnology show that the science is passing from the initial stage of the collecting of more or less disconnected facts to that of the establishment of principles."
>
> E. A. Birge and C. Juday, 1911, "The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance."

The dissolved gases study led directly to quantitative studies of plankton standing crops (Birge and Juday 1922), and still later to an investigation of the dissolved organic content of lake waters (Birge and Juday 1926, 1927a, 1927b, 1934) as a means of studying the differences among lakes in their ability to produce organic matter. As was true of much of their research, their investigations of dissolved organic matter led to the development of new techniques and equipment.

> "With 1911 began the second stage in our education. We took up the determination of the kinds, quantities, and composition of the fundamental foodstuffs produced in Lake Mendota. At first we employed the standard methods; the use of fine silk nets to strain this food from the water; the methods were modified so as to give quantitative results. But it was plain that much of the finer foodstuffs escaped through the meshes of the net and our problem was to find a way of obtaining this food in large amounts and in a shape such that further studies could be made on it. The solution came to us from Dr. Hotchkiss, the State Geologist. He had seen a milk clarifier at work in our Agricultural Department and suggested that such a machine might do our work.
>
> "This was the introduction into limnology of the continuously acting centrifuge and it

wrought a revolution in our possibilities of investigation. . . . In the years of our study we strained through the silk net more than 2000 tons of water from Lake Mendota and obtained from this water foodstuffs amounting to about one and one-half pounds of dry organic material. We ran through the centrifuge nearly 200 tons of water and extracted about 10 ounces of dry foodstuffs. . . . With this new and powerful extractor we were able to get a definite notion of the quantity of this food stuff and of its nutritive value as determined by chemistry. For the first time we had a definite notion of one important element in the lake's housekeeping. . . ."

E. A. Birge, 1936, "A House Half Built."

The study involved thousands of analyses which brought Dr. Henry Schuette and others in the university chemistry department into a collaboration more intensive than that in the dissolved gases study (Mortimer 1956). The main effort was expended in determinations of organic matter and nitrogen content. When this pioneer survey was extended to other lakes, the effort was aided greatly by the development, under Professor George Kemmerer's direction, of techniques for estimating minute amounts of carbon and nitrogen (Mortimer 1956). Like the dissolved gases study, the quantitative studies of plankton standing crops are considered among Birge and Juday's major contributions to limnology (Frey 1963, Mortimer 1956).

After 1917 Birge and Juday's efforts shifted away from the Madison region; from 1921 to 1924 they carried out intensive chemical and biological investigations of Green Lake, the deepest lake in Wisconsin. By the mid-1920s, however, their attention was drawn to the lake district in northern Wisconsin, where in 1925 they established the Trout Lake research station.

"The third stage of our education by the lakes, that from 1917 to 1924, was the most important and fruitful. . . . It culminated in the discovery that lake waters contain, in solution, a very large quantity of organics. . . . Here we had for the first time a definite notion of the total quantity of food and eaters handled by the lakes in the process of their housekeeping. . . . Thus after nearly 20 years of experience in the study of lakes we had learned to ask the question: How does a lake keep house? Twenty years had been sufficient time to teach us how to ask the question with a fair degree of intelligence, though they were far too few to give more than a hint at the answer. But we did not think little of the progress we had made.

"So we celebrated that turning point in our history by departure to new waters. Our field work on gases had made us acquainted with the lake region of Northeastern Wisconsin whose center may be placed at Trout Lake. Here is a triangular area of some 3000 square miles that contains literally thousands of lakes. These differ in every character. . . . Thus these lakes present to the student what may well be called a countless number of native experimental plots, where nature is trying out her experiments in aquiculture [*sic* aquaculture], under a wide variety of conditions and with every degree of success and failure in the limitless range of experiment.

"So we were bold enough to make the fourth period of our work a beginning of the study of a group of lakes, instead of concentrating our labors on one or two lakes or at most on a few. We hoped to get a sort of average for the varied housekeeping present in a group, and thus to arrive at a better understanding of the general principles underlying the process."

E. A. Birge, 1936, "A House Half Built."

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2 New Waters

The "Trout Lake Limnological Laboratory of the Wisconsin Geological and Natural History Survey," as it was called by Birge and Juday, was established in June, 1925, shortly after Birge retired from the university presidency at the age of 73. Birge and Juday were attracted to Wisconsin's northeastern lake district by the great number and diversity of lakes. Their hope was that by studying these lakes, which varied widely in their physical, chemical, and biological characteristics, they would discover general limnological principles.

Their research on the northeastern lakes, where the relatively soft water makes analyzing for chemical content difficult, was made possible by the development of microanalysis.

> "Dr. Pregl, Professor of Chemistry in the University of Graz, had devised methods and apparatus for what he called microanalysis, in which were employed incredibly small quantities of material. . . . The Survey purchased his apparatus in 1923, but no chemist in the University, or for that matter in the country, had ever used the method, and none seemed to think that it was a practical affair. . . . It [the apparatus] stood in my office, unused for a year or so, when it attracted the attention of Dr. Kemmerer, who was then giving much of his research time to aiding our work. He remodeled the apparatus, putting in electrical methods instead of gas. He simplified it. . . . This was the second time that apparatus had revolutionized our work, the first being the use of the centrifuge in obtaining plankton. The centrifuge and microanalysis have made limnology into a new and wholly different science."

E. A. Birge, 1936, "A House Half Built."

For the first three years the research station was in an old schoolhouse and garage near the Wisconsin State Forestry Headquarters on Trout Lake. Part of the garage building served as an office and laboratory. The chemistry laboratory was in the nearby schoolhouse. Birge had a room in the Forestry Headquarters Building for sleeping, but Juday and the others slept in tents on the lake shore and ate their meals with the forestry workers (R. Robinson 1983, personal communication). Beginning in 1927 Juday brought his family to Trout Lake, and they stayed in a log cottage near the station. Juday's son Richard, who later graduated with a Ph.D. (1943) in chemistry from the University of Wisconsin, began helping as a field assistant in 1934.

> "I started rowing Dick Wilson around in '34. From then through the summer of '40 I worked every summer here. Before that, we had cabins in various places. Sometimes, I'd just go out and Father would say, 'Well, we're going to such and such lakes,' and then we'd go tag along."

R. Juday, 1983, "History of Limnology in Wisconsin Conference."

Just getting to the northeastern lake district was a major feat in itself. In 1925 there were only 20 miles of paved roads between Madison and Trout Lake. The other 200 miles was rough gravel. On one of his first trips to Trout Lake Juday broke an axle on his Model T Ford (R. Juday 1983, personal communication). Getting out to the lakes to get samples was also no easy task.

> "We used a Model T Ford for transportation to the neighboring lakes. The 'improved' roads were gravel and became very rough during heavy summer usage. Remote lakes were served with dirt roads, usually of very poor quality. Many lakes were inaccessible except by trail. We made use of rowboats at resorts whenever available. If no boat was available, we set up a portable wood-frame canvas boat or inflated a portable rubber boat. A few times one of us would swim out a distance from shore to take a water temperature and obtain a water sample."
>
> R. Robinson, 1983, personal communication.

If one of the researchers swam, it was not Birge or Juday, as neither of these eminent limnologists could swim (A. Hasler and R. Juday 1983, personal communication). However, Juday's daughter, Mary, notes that her father could swim a little (M. Juday 1987, personal communication).

Even though the facilities were modest, the staff grew from three biologists (Birge, Juday, and Stillman Wright, a graduate student of Juday) and one chemist (Stanton Taylor, a graduate student of George Kemmerer) in 1925 to seven biologists and three chemists by 1928. By the mid-1930s there would be as many as twenty-two scientists and assistants at the Trout Lake Station each summer.

In 1928 the Wisconsin Conservation Department (later the Department of Natural Resources) gave the Survey permission to use two wooden bathhouses on the shore of Trout Lake for permanent laboratories. Birge and Juday had another building constructed, and every few years added an additional building to the station facilities. Some were built during the Depression of the 1930s using WPA labor.

Juday was the director of the research station from 1925 until his retirement in 1942. During those years the north-central lake district was the main center for limnological research at the University of Wisconsin. The approach at Trout Lake was not so much problem oriented or lake oriented. The researchers were concerned primarily with surveying large numbers of lakes for various chemical and biological properties and studying the range of variation of these properties and their presumed controls, especially as they related to drainage and seepage lakes (Frey 1963). Under Juday's direction, and with the help of student labor, more than 500 lakes were examined, chiefly during the period 1925 to 1932, for water chemistry, plankton, and for the intensity and color of underwater illumination. A complete set of field determinations comprised 19 different chemical, physical, and biological items (Frey 1963). George Kemmerer directed the chemical work for Birge and Juday at Trout Lake and in Madison from 1925 to his death in 1928. Rex Robinson was a graduate student working under the direction of Kemmerer.

> "During the summers I was at Trout Lake we investigated well over 500 lakes in Vilas and adjoining counties. . . . As most of the lakes had not been investigated limnologically before, we would first sound the lake for depth with lead and calibrated line to establish our station at the location of deepest depth. Water temperatures at different depths were taken to establish the thermocline. Samples of water and plankton were then taken at appropriate depths. Readings for turbidity were usually taken with the Secchi disc.
>
> "After our samples were taken we would hurry home to the laboratory for the analytical work. Thousands of analyses were made during the summer's work. The normal list included: pH, dissolved oxygen, free and fixed carbon dioxide, soluble phosphate, organic phosphorus, soluble silicate, nitrate, nitrite, ammonia, organic nitrogen. Each day the results were reported

to Dr. Birge or Dr. Juday. Dr. Birge evaporated water samples to determine water residue and also to obtain samples for C-H analyses later in Madison. Dr. Birge made light penetration measurements by making measurements at different water depths with a photometer. He also made measurements for different bands of wavelengths by covering the eye of the photometer with different colored glass filters. . . .

"Our lives were busy ones. Breakfast at 7 a.m. and off to the selected lake(s) of the day as soon as we could load up the auto with the necessary bottles and needed equipment. We worked seven days a week. The only diversion for the young folks was fishing on Trout Lake or the Saturday night dance at the Trout Lake Dance Pavilion at the south end of Trout Lake. But those were pleasant summers and I treasure the memories."

R. Robinson, 1983, personal communication.

The period from 1925 to the early 1940s was an extremely productive time for the two limnologists and their many colleagues. At the University of Wisconsin, zoologists, botanists, chemists, bacteriologists, geologists, and others were being drawn more and more into a cooperative program (Frey 1963).

"The research that was being carried on up here was really at the forefront of limnology around the world. . . . Even though they were doing these extensive studies here, they were also doing the intensive studies on the six lakes. [Trout, Nebish, Weber, Crystal, Muskellunge, Silver (Sparkling)]. They were involved in really current things."

D. Frey, 1983, "History of Limnology in Wisconsin Conference."

The research Birge and Juday wanted to conduct required the participation of people from many disciplines and a large number of "helping hands." Birge was particularly well placed in Madison to obtain those "helping hands." As former Dean and President he could enlist the help of university chemists, biologists, bacteriologists, physicists, and instrument-makers. He was able to obtain financial support for the work, for equipment, and for assistance in the field.

"One of Birge's great contributions was his ability to go across the university and find the expert he needed. There weren't many places in the world where you had such a combination of talent. Birge's political savvy and his aggressiveness, combined with his having attained a leadership role in the university at a very young age, enabled him to get both money and experts."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Most of the funding for research conducted during this period came directly from the state through the Geological and Natural History Survey. Birge and Juday also obtained money from the university, the Wisconsin Alumni Research Foundation, the Wisconsin Conservation Department and the U.S. Bureau of Fisheries, with whom Juday maintained a consulting and cooperating relationship for many years. The limnologists also received substantial funds from private sources, such as the Brittingham Fund, which was established by Thomas Brittingham in 1927 with the understanding that his gifts would be applied to subjects that were of "prime scientific importance, yet so complex and so remote from immediate practical use that we [Birge and Juday] did not think it right to employ the limited state funds in their study" (Birge 1940). Birge and Juday were not above a bit of "book juggling" to get additional funds for equipment.

"They did have one unique way of getting funds. They were able to get some money from the Bureau of Fisheries for labor. If they needed equipment they would put somebody on the payroll for a month. When the check came, that individual endorsed it and they bought the equipment. I know I endorsed several of those checks."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

The involvement of so many people in the research program at Trout Lake and in Madison makes their contributions to limnology difficult to summarize. The single major effort at Trout Lake was the broad survey involving more than 500 northeastern lakes. Juday and Birge (1933) reported on transparency, color, and specific conductance for most of these lakes. Following Kemmerer's death, direction of the chemical work was taken over by Villiers W. "Mel" Meloche, who was a pioneer in the application of new instruments to chemical analyses. In the chemical reports, which were written in association with Meloche, the researchers reported analyses of silicon, iron, manganese, calcium, magnesium, fluoride, chloride, sulfate, and ammonia, nitrite, nitrate, and nitrogen. The ranges and frequency distributions were given, as well as the distribution with depth and the relation to the general chemical conditions in the lakes (Juday, Birge, and Meloche 1938). They also reported on phosphorus content (Juday and Birge 1931), sodium and potassium (Lohuis, Meloche, and Juday 1938), dissolved oxygen and oxygen consumed (Juday and Birge 1932), and carbon dioxide and pH (Juday, Birge, and Meloche 1935).

"I provided the chemists and Birge and Juday provided the facilities. . . . I brought up platinum dishes to evaporate water to get residues. We took the samples back to Madison, and, with the help of assistants, we analyzed the residues for chemical content. . . . We made the best use of the available equipment and invented equipment that would make the analyses faster. Advances in instruments opened new fields of research.

"The great advances in physical, analytical chemical instrumentation occurred close to the end of the war in 1945. Prior to that, much was done by the 'guess by gosh' method."

V. Meloche, 1979, personal communication.

One of the assistants to Meloche was Fredrick Stare, who later founded the Department of Nutrition at Harvard University. When he was at Trout Lake he was an undergraduate majoring in chemistry. Stare recalled that it was not all work and no play.

"I enjoyed very much working with Meloche up here. We used to go trout fishing with homemade reels. We'd take two pie plates and put them together somehow. In the flange between the pie plates you could wrap quite a bit of string. We used to catch loads of trout way down deep—100, 110, 125 feet. It was loads of fun."

F. Stare, 1983, "History of Limnology in Wisconsin Conference."

It may have been the assistants, many of whom did not have their own thesis projects to work on, who had the most fun at Trout Lake. Bradford Hafford worked as a chemistry assistant in 1939 and 1940.

"On Trout Lake we generally trolled for walleyed pike in the evening for supper. After sexing the catch, we would filet and eat them—delicious. My wife Jean caught the largest walleye on our side of the lake, about a six pounder. The record only held for about a day when Dick Juday brought in a fish one half pound larger. It developed later that Dick had stuffed his fish with more than one pound of lead sinkers before weighing."

B. Hafford, 1983, personal communication.

Life at Trout Lake was certainly far more work than play, however. In addition to the broad chemical and biological survey of lakes, Birge and Juday selected for intensive study six lakes that covered the range of chemical and biological conditions found in northern lakes.

> "The research assistants were organized into crews with two or three assistants per crew, a fish crew, a microbiology crew, a chemical crew, and a plankton crew. . . . I was on the plankton crew and regularly about every ten days, we would visit one of six lakes that were chosen for intensive study. These were Trout, Nebish, Weber, Crystal, Muskellunge, and Silver [Sparkling] lakes.
>
> "Early on most mornings we would hitch up the boat and trailer to the plankton truck, we went out and took our chemical samples, took the plankton samples and brought them back to the laboratory. We went out in all kinds of weather. If it rained that day it didn't make any difference, you went out anyway. If it was windy, you went out anyway. We used these heavy old oak boats in those days. There were no life preservers. The boats were heavy, but none of us ever worried about having the boat dump over. If it had dumped over, I'm sure we would have drowned. . . . We never gave it a thought and worked along blissfully. . . .
>
> "We would come back with our water samples late in the morning or around noon and then the chemists would run pH, carbon dioxide, dissolved oxygen, and so forth, and either I or someone else would run the plankton samples through the Foerst centrifuge for phytoplankton counts. We used the Juday plankton trap for quantitative zooplankton counts. In addition to our regular chores of taking plankton and chemical samples, we often had other temporary assignments given to us. For example, frequently, once or twice a week I would be required to go out and take bottom fauna samples. We'd use an Ekman dredge and a Peterson dredge and bring the samples back to the lab and count the bottom organisms and have it entered into the record."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Although Birge was into his 80's by the time the survey investigations were in full swing, he was a determined and relentless researcher.

> "One time I was driving Birge over near Sayner somewhere. We were on a gravel road and we came around a curve and somebody came toward us. We couldn't get out of the way and the little Model A slowly tipped on its side. Birge had been sitting next to me and was now down on the lower side of the tipped car and I was up against him. Birge was now 85 years old. I managed to get out of the left door of the car and I helped haul Birge out of the thing too. It had tipped over so gently there wasn't any appreciable damage to it. And we both got around and saw the dumped over car just off the edge of the road and Birge, being a devout churchman said, 'Goddammit Pennak, put it back on its wheels, the Survey must go on.' "
>
> R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

At the Trout Lake Station Birge continued his studies of light penetration that he had begun in Madison in 1912. He had been the first to measure the penetration of sunlight into a wide range of lakes with precise equipment. Birge used a "pyrolimnometer," an instrument produced by collaboration with university physicists. The instrument measured the total energy of the sun's rays by the electrical effect they produced when falling on the sensitive surface of the thermopile. Using the pyrolimnometer, Birge, with the assistance of a student helper, Hugo Baum, measured the transmission of solar radiation and the factors influencing the differences in transmission observed among lakes and from one depth to another in the same lake. Lester Whitney, who conducted several studies of light transmission (1938, 1941), extended Birge's measurements on light transmission to intensities as small as 2 x 10^{-6} of surface light by means of a photoelectric cell and an amplifier.

"Les Whitney was a marvelous technician. He was marvelous at cooking up apparatus. I had an electronic thermometer that was custom-made for me by Les Whitney that would read temperatures to a hundredth of a degree and get reliable replicates from one reading to another."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

With the help of J. P. Foerst, a mechanic and instrument maker in the Physics Department, Birge and Juday and their colleagues developed new instruments or modified existing ones. From rough sketches or from suggestions as to the kinds of data needed, Foerst was often able to devise pieces of equipment, many of which are standard items even today (Frey 1963).

"Somehow Birge and Juday got money to pay Foerst specially to concoct instruments for them in the physics workshop. They modified the Ekman dredge, which had originated in Sweden. They invented the Kemmerer water sampler. Juday, along with Birge I suppose, invented the plankton trap—various sizes of it. And Foerst built for Juday the little Foerst centrifuge that was used for centrifuging water samples to get out the phytoplankton and seston determinations. . . ."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

The equipment invented, particularly the super-centrifuge, was not always considered entirely safe by the research assistants.

"Both Birge and Juday were anxious to get out every bit of colloidal material that was in the water. They weren't satisfied with the Foerst centrifuge, which works on the same principle as a cream separator. So they got hold of an air compressor that could deliver 200 psi constantly. It was said to be the largest portable air compressor in all of northern Wisconsin. That thing was installed in the Plankton lab on a concrete base and it delivered this jet—actually a multiple jet—of compressed air against a rotor that we were using to try and separate out little tiny fractions of colloidal particles still left in the water. It was a terrifying thing. All of us were frightened to death of it. It had a rather large rotor and we were afraid that at the speed at which it was running— it would run on a cushion of air— that the bowl would fly apart. As a result we built a heavy protective covering for the thing out of 2 x 4's. We used to turn the thing on, quick run out of the lab, and assume a low profile in the event that the thing ever blew apart."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

George Clarke, a visiting scientist from the Woods Hole Oceanographic Institute, perfected the Clarke-Bumpus sampler while at Trout Lake. And Herbert Dutton, a postdoctoral student working with physical chemist Winston Manning and chemist Farrington Daniels, also used equipment that was ahead of its time in his research on chromatic adaptation in relation to color and depth distribution of freshwater phytoplankton and large aquatic plants at the Trout Lake Station in 1940.

"I used a spectrophotometer before there were spectrophotometers. It was a glass prism about

12 inches tall. When I did my first measurements of the absorption spectra of pigments it was a matter of watching a galvanometer on a meter stick. But it was an effective instrument.''

H. Dutton, 1983, ''History of Limnology in Wisconsin Conference.''

As the work of Birge and Juday and their colleagues became better known, they began attracting the attention of the European limnologists who began citing their work and visiting the University of Wisconsin and the Trout Lake Station. Certainly in Madison, faculty and students interested in limnology recognized that Trout Lake was the ''place to be,'' that good and important research was going on there.

''We chemistry students knew about Trout Lake as an exciting, challenging place to live and work. . . . There was an aura about coming to Trout Lake. If you were real good and real lucky you might have that opportunity. So I think the people that came up here, came up quite starry-eyed and were the top people.''

H. Dutton, 1983, ''History of Limnology in Wisconsin Conference.''

While at the Trout Lake Station, graduate students and other researchers had very little contact with Birge even though he continued to come up to the station every summer through 1938. Juday was the one who directed the research and the students.

''Juday was the real clearinghouse. We all talked with him and I think Juday talked with Birge. . . . Dr. Birge didn't have a great deal to say. He would ask a very pointed question at times. But he never really had any suggestions.''

L. R. Wilson, 1983, ''History of Limnology in Wisconsin Conference.''

''Birge was a driver, he was the front man, he was the publicity man, he was the fund-raiser as I pictured it. Juday was kind of in the background in those things. Yet he was the consistent, steady slugger. I think he probably had more of the ideas than Birge had.''

E. Schneberger, 1983, ''History of Limnology in Wisconsin Conference.''

Their associates at the Trout Lake Station were largely unaware of Birge and Juday's scheme of research, but there was no question that the pair had long-term plans for their research program.

''During my first year as a graduate student [1934] I was assigned the task of presenting to a proseminar group a paper on aspects of the life of Professor Birge as an outstanding biologist. . . . He [Birge] graciously gave me over an hour's time and during this time outlined the 10 year research program he had in mind. He was about 85 years old at the time.''

C. Schloemer, 1983, personal communication.

The students and technicians always knew in detail what they would be doing from day to day, but the outline of the research plan and the goals of the research were never discussed with them. Juday rarely went out into the field with the research assistants except to show them how to take samples (Pennak 1983, personal communication).

''Certainly there was a fabric and plan laid out by Dr. Juday's broad concepts, but it was such that we really couldn't interpret quite what the overall pattern was. . . . You had the feeling that you had a specific problem and you did it. You didn't quite see the broader aspects and implications of the particular research you were doing, where it fitted in. . . . Certainly there was no overview of where we were going."

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

The problem of communication was exacerbated by the lack of seminars or any formal set-up for the exchange of ideas. There were certainly discussions around the poker table in addition to the "I'll raise you 30," as well as conversations that were a combination of shop talk and story-telling around bonfires on the beach. In later years students did discuss ideas and research problems over the dinner table. Neither Birge nor Juday, however, participated in these activities. Nor did Birge and Juday introduce their students to the many European researchers who visited Trout Lake or the university.

"In the four summers I was here we didn't have a single seminar presentation. . . . This is one reason why theory and empirical ideas simply did not come out in the open because we did not have this kind of discussion."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Graduate student theses were, for the most part, independently conceived and executed. There was very little guidance from either Birge or Juday. Students were given a free hand and time to do their own research while they worked for Birge and Juday, but it was an individualistic effort—the student was on his own to either sink or swim. Fortunately, most swam.

Funding for the Trout Lake Station had always been relatively meager, but in 1931 the Wisconsin state legislature discontinued funding for the natural history portion of the Geological and Natural History Survey. The funding cut-off may have had as much to do with old political rivalries as the Depression of the 1930s.

"Dr. Birge and Bob LaFollette, Sr., got to be rather bitter enemies when LaFollette was governor [Birge was then university president]. They differed on how they thought the university should be operated. Dr. Birge was quite insistent on trying to keep the activities pretty well within the bounds of the campus, while LaFollette wanted the university spread out, to be of more service to the people of the state. . . . So when LaFollette's son Phil became governor, that animosity apparently continued because with one stroke of the pen, he wiped out the funds for the natural history part of the budget, which left Juday and me out of a job. But the university came to the rescue and took it over. So after that it was funded by a university appropriation and Juday was given university status [full professorship in zoology, formerly he had been a half-time lecturer]."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

Living and working conditions at the Trout Lake Station had never been luxurious, but the Depression made things even worse. There was no running water or electricity in the living quarters, and the ice box was a hole in the ground insulated with *Sphagnum* moss.

"In 1935 we all lived in a leaky tarpaper shack that served as both bunkhouse and cookhouse. In later years we had a frame bunkhouse. . . . This was Depression time and we were just recovering from the Depression of the '30's. . . . We worked from about 7:15 to about 4:30 or 5:00, six days a week, although we did very little on Saturday afternoons. Sunday we were free.

We slept, did our laundry, we read, we loafed. There was no booze. There wasn't even any beer. There were no radio stations in the area, so a radio up here wouldn't do you any good. . . . Saturday nights most of us would indulge in a poker game or otherwise we would go into Minocqua and walk up and down what was then the entirety of Minocqua, about three or four blocks long and one block deep."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

"My impression of the Trout Lake laboratory [1939 and 1940] was that we were very poor. All the equipment was very much out of date . . . trucks literally falling apart . . . the boats were in bad order. Oars were short—it was almost a matter of stealing oars from one another to get a good oar to go with your boat. We had no more than three or four motors at that time and it was hard to keep the motors running. It was really in poor shape."

C. Kirkpatrick, 1983, "History of Limnology in Wisconsin Conference."

Despite the Depression and the harsh conditions it imposed, the research program at Trout Lake flourished. In addition to the lake survey work, Birge and Juday's colleagues and students at Trout Lake made wide-ranging studies of lake sediments and sedimentation processes, aquatic bacteria, aquatic plants, psammolittoral organisms, fisheries ecology, and lake productivity and community structure. (A complete list of the papers published by Birge and Juday and their associates can be found in C. Juday and A. D. Hasler, 1946. A list of publications dealing with Wisconsin limnology 1871–1945. *Trans. Wis. Acad. Sci. Arts Lett.* 36: 469–490.)

Juday, Birge, and Meloche (1941) published an extensive paper on the chemistry of lake sediments involving 18 lakes in northeastern Wisconsin and three in southeastern Wisconsin. W. H. Twenhofel, a geologist from Madison, and his students, W. A. Broughton and Vincent E. McKelvey, studied sediments and sedimentation both in the Madison area and at Trout Lake. Paul S. Conger, a visiting scientist from the Carnegie Institution in Washington, examined diatoms in sediment cores in Crystal Lake and was one of the first researchers to use diatoms to interpret previous ecological conditions in a lake. Pollen chronologies in lake and bog sediments were examined by Leonard R. Wilson and John E. Potzger, a visiting scientist from Butler University.

Birge and Juday recognized early the importance of bacteria in lakes. Their early studies on numbers of bacteria in Mendota were continued by E. B. Fred and Letitia M. Snow. Claude E. ZoBell was a visiting scientist from Scripps Institution of Oceanography when he studied the role of bacteria in lake metabolism. Ruby Bere was one of the first persons to make direct microscopic counts of bacteria in waters. Studies of this type were extended by William Stark and Elizabeth McCoy in the lakes of northeastern Wisconsin. During this interval quite a number of persons, including Yvette Hardman, William Stark, Mary A. Jansky, and Dorothy E. Kinkel, received Master's and Ph.D. degrees in bacteriology on problems directly related to limnology (Frey 1963).

Gerald Prescott, widely known for his research on algae, came from Albion College and later, Michigan State University to work at Trout Lake in the late 1930s. His book, *Algae of the Western Great Lakes Area* (Cranbrook Press) was based on these investigations. In 1952 he would receive the first grant for ecological research ($3900) from the National Science Foundation for "Ecological Survey of Arctic and Alpine Algae in Relation to Glaciation and the Disjunctive Distribution of Phanerogams" (Burgess 1981). Prescott was also renowned as the best poker player at Trout Lake.

"My excuse for having been here was my interest in algae and the work on phytoplankton that G. M. Smith did back in the 1920s on these same lakes. . . . Dr. Birge, through the Wisconsin Geological and Natural History Survey, picked me to complement his studies and do the filamentous and other groups of algae. . . .

"Birge and Juday encouraged my interest in relating types of flora to water chemistry and to fish production . . . to get a bird's eye view of the kinds and quantities of algae in different kinds of lakes and relate that to the chemistry and to the amount and kinds of fish produced. . . . In my wanderings I tried to visit every and almost any lake in this whole area.

"I came to this lake in Boulder one afternoon. I didn't bother anybody else and waded out with my little scum skimmers to do my collecting. In a very short time the director of the camp [YMCA] came out on the porch and bellowed out, 'What are you doing out there?' The wind was blowing and I didn't know what to tell him. I couldn't explain about algae and fish food organisms and so forth. He kept bellowing at me. I felt really embarrassed, so I made my collection and left. I felt so guilty that I wrote a letter to the director and apologized for not giving him a full six weeks' course in algae with the wind blowing against me. The net result was that he sent me an invitation to come out and have dinner with the boys."

G. Prescott, 1983, "History of Limnology in Wisconsin Conference."

Norman Fassett, Leonard R. Wilson, John E. Potzger, and Willard A. Van Engel studied the distributions of aquatic plants in lakes varying widely in chemical and biological characteristics. They were concerned with communities or associations of plants in relation to soil type and depth zone. Wilson was also interested in the successional relationships of communities from primitive lakes with inorganic soils to advanced lakes with organic soils, and he attempted to relate the distribution and abundance of aquatic plants to various environmental factors (Frey 1963). Wilson's research was, of course, done before the advent of SCUBA gear.

"The first summer we worked on Weber Lake my wife rowed the boat while I had a little square of iron that I dropped down. Then I'd dive down and pick up plants and bring them to the top. I crawled over most of Weber Lake bottom right to the extent of the attached vegetation. . . . I think I also crawled over more of the bottom of Trout Lake than anybody in existence. We did something like 68 transects and it was a tremendous job."

L. R. Wilson, 1983, "History of Limnology in Wisconsin Conference."

Robert Pennak, a graduate student of Juday's, pioneered in the study of the psammolittoral community—organisms living in interstitial water on beaches. He collected extensive data on the horizontal and vertical distribution of the various organisms and on the chemistry of the psammolittoral zone.

"After I did my thesis work and it was published in *Ecological Monographs* (1939) as an 80-page paper—of course you couldn't get a paper that long accepted these days—it immediately attracted the attention of marine biologists. In 1939, the year after I got my degree, I went to Wood's Hole and did a similar project on Wood's Hole beaches with reference to the tide lines. We discovered that there is indeed a similar kind of assemblage of microfauna on sandy ocean shores.

"Now this was pioneer work—nobody had done anything like this ever. Since those days very little of this kind of work has been done on freshwater, but in the ocean the thing has absolutely burgeoned. So now there is an international society of myobenthologists and they publish their own journal having to do with organisms living in—they've now gone down into the mud bottom below tide level as well—the sandy beach area here . . . but in freshwater habitats there's been almost nothing done since I did my pioneer work back now so many years ago."

R. Pennak, 1983, "History of Limnology in Wisconsin Conference."

Minna Jewell, from Thornton College in Illinois, spent several summers at the Trout Lake Station studying freshwater sponges. She had studied stream ecology with Victor Shelford at the University of Illinois and had hoped to conduct research on water pollution. She began studying sponges at the suggestion of Edward Schneberger, a former student.

"Two things were wrong about her continuing her profession: her desire to study stream pollution—people weren't accepting those things in those days—and women's lib hadn't come along yet, so being a woman, she had trouble finding employment. . . . I felt she was going to pot at Thornton and needed some activity to use her talent. I had seen these sponges in lakes here and I conceived the idea that that would be a good project for her."

E. Schneberger, 1983, "History of Limnology in Wisconsin Conference."

Jewell was somewhat eccentric—she wore G.I. clothing from World War I and called her sponges, "spon-jāz" (Pennak 1983, "History of Limnology in Wisconsin Conference"). She is most fondly remembered, however, as someone who was always ready to take a struggling student "under her wing."

Juday and Birge had been receiving research support from the U.S. Bureau of Fisheries for some years, but with the establishment of the Trout Lake Station they also began receiving support for research on fish from the Wisconsin Conservation Department. This phase of aquatic investigation at the University of Wisconsin may be considered to have started with the study begun in 1925 by Stillman Wright on the growth of the rock bass. From this time on there was a steady succession of papers concerned with various aspects of fishery biology and management, including a number of now classic papers by Ralph Hile on cisco and rockbass. Hile was a recent graduate of Indiana University and was employed by the U.S. Bureau of Fisheries. He was sent to work with Birge and Juday, and he and Schneberger worked together on much of the fisheries research conducted at Trout Lake. Schneberger later became Head of Fisheries for the Conservation Department and was instrumental in arranging for the continuation of cooperative fisheries research between the university and the department.

Other papers in fishery biology were written either by Juday, based on data gathered by WPA workers, or by students, such as Edward Schneberger, Clarence Schloemer, George Bennett, William Spoor, and David Frey, who received their Ph.D.'s under Juday's supervision (Frey 1963).

One very important paper of this period described the method developed by Zoe Schnabel (1938) and her colleagues, E. Hull and M. Ingraham in the Mathematics Department, for estimating the size of a fish population by marking and recapturing. Schnabel's work was done between 1936 and 1938 when she was a graduate assistant in the Computing Laboratory of the Mathematics Department in Madison.

"The laboratory had been established in the early 30s to assist university researchers with the statistical analysis of data. Members of the mathematics faculty served as consultants and I and an assistant did the computations, using a standard 8-bank calculator and a manual-type 13-bank model which had been motorized. Dr. Chancey Juday . . . was one of the first persons to use the laboratory. He and his associates were doing studies on the fish populations of several Wisconsin lakes using capture-recapture procedures. My paper of 1938 summarized the methods which had been developed in the laboratory for estimating population size."

Z. Schnabel Albert, 1980, in letter to David R. Anderson.

In the last decade of his productive life as a limnologist, Juday turned his attention to the measurement of the rates of energy fixation and the subsequent utilization of energy within the trophic structure of the ecosystem (Frey 1963). Juday and his associates made some fundamental contributions to this area of research. Plant ecologist John T. Curtis and Juday, for example, conducted one of the very early bioassays of productivity. In 1936, Winston Manning, a physical chemist at the University of Wisconsin, joined the summer program at Trout Lake with a much more sophisticated approach toward productivity. Herbert Dutton, a post-doctoral student advised by Manning, conducted some of the earliest field research on chromatic adaptation.

"I was working with Dr. Manning and we had just discovered that carotenoids absorbed energy and transferred it to chlorophyll A with an efficiency almost equal to the chlorophyll in chlorophyll B or chlorophyll A itself. So the logical extension of that was, 'how did it work in real life and how would it do in Trout Lake—is there any chromatic adaptation?' So far the study was a matter of examining the family of *Potomageton* as it extended out into Trout Lake to see whether there was any correlation of color with depth."

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

During World War II Manning worked on the Manhattan project and later became the Associate Director of Argonne National Laboratories. He had asked Dutton to join him on the Manhattan project, an offer Dutton reluctantly turned down.

"Winston Manning wrote to me and said, 'We have a discovery that is as important as x-rays. (This was the Manhattan project.) Would you like to join us?' I went to my bosses in the government and they said it was not important work and that what I was doing [analyzing dehydrated foods] there was much more important. They told me, 'If you want to go, go, but your job won't be here when you return.' "

H. Dutton, 1983, "History of Limnology in Wisconsin Conference."

Other research on lake productivity included the first study of the amount and distribution of chlorophyll in lakes, which was carried out on northeastern lakes in 1937 by Zygmunt Kozminski, a visiting scientist from the Wigry Hydrobiological Station in Poland. In two other papers Juday attempted to set up an energy budget for Mendota (Juday 1940) and to investigate the relationships between various components of the standing crop of organic matter (Juday 1942). Perhaps the most important study in this series was the last one by Juday, J. M. Blair, and E. F. Wilda (1943) in which the daily productivity for an entire lake was determined from continuous records of dissolved oxygen at several depths, as measured by dropping mercury electrodes (Frey 1963). Juday also attempted to increase production in Weber Lake by adding fertilizers. He and his colleagues tried various commercial mineral fertilizers, as well as soybean meal and cottonseed meal.

Despite the large number of research projects conducted during this era, relatively few students received graduate degrees under the direct supervision of Birge and Juday. Very early in his career Birge took on heavy administrative duties that probably precluded supervising graduate students. By the time he and Juday established the Trout Lake Station, Birge was already 73 years old. During the late 1800s Birge did supervise a number of Bachelor's theses and a few Master's theses including those of Julius Nelson and Ruth Marshall, but Birge never had any Ph.D. students. Juday had been hired as Biologist with the Wisconsin Geological and Natural History Survey with a simultaneous appointment as Lecturer in the Zoology Department. He was not made a professor until 1931 when he was 60 years old and did not begin supervising students until late in his career.

Juday's first Ph.D. students were Stillman Wright, Edward J. Wimmer, and Abraham H. Wiebe, who completed their degrees in 1928 and 1929. Juday supervised the Ph.D. research of ten other students including Willis L. Tressler (1930), J. P. E. Morrison (1931), Ruby Bere (1932), Edward Schneberger (1933), William A. Spoor (1936), Arthur D. Hasler (1937), Robert W. Pennak (1938), George W. Bennett (1939), Clarence L. Schloemer (1939), and David G. Frey (1940). (A list of Juday's Ph.D. students and their theses is included in the Appendix.) Even though Juday had only 13 Ph.D. students during the "Trout Lake years" a number of students in the departments of Botany, Chemistry, Geology, and Bacteriology received Ph.D.'s based on limnological research.

Mortimer (1956) suggests that Birge and Juday's survey work at Trout Lake did not contribute as significantly to limnology as did their research on Wisconsin's southern lakes, partly because a great deal of the data they collected on northern lakes was never fully analyzed.

> "The plankton studies were never published, the bottom fauna studies were never published, the super-centrifuge studies were never published, the seston data were never published. These are golden data because they represent samples taken in the same way over a whole series of years from the same series of lakes, the like of which does not exist anywhere in limnology. I greatly regret that Juday did not live long enough or give the data to somebody else to work them up for publication. . . . They should be published somehow or other because there will be an enormous demand for them. They are unique, they are massive, and for this reason mean a lot to limnology as a whole."
>
> R. Pennak, 1983, "History of Limnology in Wisconsin conference."

Not only did much of their data remain unanalyzed, but Birge and Juday did not attempt to put their data on various aspects of the physics, chemistry, and biology of lakes into any kind of larger picture, or to build any type of limnological theory from their observations. Most of the papers published using data from the 500-lakes survey were concerned less with interpretation of results than with descriptive presentation (Frey 1963). They were certainly in tune with the times, as the ecological sciences in North America from 1920 to 1950 were largely descriptive rather than theoretical (Egerton 1977). Juday, in particular, disdained the new mathematical approach to limnology.

> "[Edward] Deevey tells me that H. [G. Evelyn Hutchinson] is writing a book on Limnology and it is to be chiefly mathematical. So you can look forward to the worst."
>
> C. Juday, 1941, letter to R. Pennak.

> "The Yale school of mathematical-limnologists is having a high time displaying their mathematical abilities. The interesting part about it is that they are applying mathematical for-

mulae used in sub-atomic physics where all of the forces are presumably uniform to limnological problems where there are all sorts of un-uniform factors involved, such as differences in temperature in different habitats, in waves and currents, in soil substrata, etc. Apparently they do not have brains enough to see the point in the two very different situations. It is quite interesting to see that Deevey seems to think that a single sample from the bottom of a lake may be sufficient to tell the story of the bottom fauna, so why take more. He can prove mathematically that it is adequate. In a short time I shall expect them to tell all about a lake thermally and chemically just by sticking one, perhaps two, fingers into the water, then go into a mathematical trance and figure out all of its biological characteristics. As the next stage in their evolution they will probably be able to give a lake an 'absent treatment' similar to a spiritualist, so it will not be necessary to visit a lake at all in order to get its complete chemical, physical and biological history. Then all limnological problems will soon be solved and they will be looking for greener pastures. Such is life in limnology."

C. Juday, 1942, letter to R. Pennak.

When Juday was asked in 1941 to review for the journal *Ecology* Raymond Lindeman's now classic paper on energy flow in ecosystems (Lindeman 1942), he recommended that the paper be rejected because there were insufficient data to support the theoretical model and because he felt theoretical essays were inappropriate for *Ecology* (Cook 1977). The same recommendation was made by Paul Welch of the University of Michigan. At that time Juday and Welch were considered the two most prominent limnologists in the country (Cook 1977). Lindeman's paper was accepted for publication in 1942 despite Juday and Welch's severe criticism.

". . . a large percentage of the following discussion is based on 'belief, probability, possibility, assumption and imaginary lakes' rather than actual observation and data. . . . According to our experiences, lakes are 'rank individualists' and are very stubborn about fitting into mathematical formulae and artificial schemes proposed by man."

C. Juday, 1941, review of Lindeman's paper for *Ecology* as quoted by Cook (1977).

"It seems to me unfortunate if the space which should be occupied by research papers is partly consumed by 'desk produced' papers unless they be of a most unusual and significant kind. In my humble opinion this kind of treatment is premature. Limnology is not yet ready for generalizations of this kind. . . . What limnology needs now most of all is research of the type which yields actual significant data rather than postulations and theoretical treatments."

P. Welch, 1941, review of Lindeman's paper for *Ecology* as quoted by Cook (1977).

G. Evelyn Hutchinson, who with his students would lead the way in theoretical ecosystems ecology and limnology, came to the defense of Lindeman's paper. Lindeman had gone to work with Hutchinson at Yale University in 1941 after completing his Ph.D. degree at the University of Minnesota. Hutchinson's response to Juday and Welch's reviews contained an implicit criticism of Birge and Juday's research on Wisconsin's northern lakes.

"Far from agreeing with Referee 2 [Welch] as to what limnology needs, I feel that a number of far-reaching hypotheses that can be tested by actual data and which, if confirmed, would become significant generalizations, are far more valuable than an unending number of marks on paper indicating that a quantity of rather unrelated observations has been made. . . .

"At times I have felt quite desperate about the number of opportunities that have been missed in the middle Western regions for obtaining data confirming or disproving the hypotheses that have been forced on us by our little lakes."

G. E. Hutchinson, 1942, response to Juday and Welch's reviews of Lindeman paper as quoted by Cook (1977).

W. T. Edmondson had graduated from Yale in 1938, having worked in Hutchinson's lab since early high school. He spent a year at the University of Wisconsin, including a summer at Trout Lake working on sessile rotifers, before returning to Yale for a Ph.D.

"Yale and Wisconsin were vastly different. The Wisconsin emphasis seemed to be to assemble measurements of some property from a large number of lakes, finding ranges and means (many of the standard statistical techniques used commonly today had not yet been invented). There was a little but not much attempt to notice relations between variables, and minimal attention to the limnological processes that would connect them together, e.g. the oxygen and phosphorus cycles. There was some trend in that direction, but it had not got very far in 1939. Some visitors were plowing new ground, as Manning with measurements of photosynthesis. There were some gestures toward experiments, as with the ineffective lake fertilization studies. This whole approach may have been conditioned by the summer laboratory system; measure something like mad all summer, then spend the winter doing arithmetic to find out what you had.

"In New Haven, there was plenty of data gathering, but it was directed at something other than a statistical description of a population of lakes. I have seen Hutchinson come in from a lake and spend the rest of the day running phosphates, titrating oxygens, filtering samples, and then running up the results with a slide rule, but some ideas had been thought out ahead of time and the particular samples were collected for a purpose beyond just finding out what was there."

W. Edmondson, 1983, personal communication.

Limnology was such a new science and there were still so few limnologists in the world that the research conducted by Birge and Juday and the scientists and students working with them must still be considered pioneering and a major contribution to the understanding of limnological processes.

"One of the great contributions of the team was in how they observed. . . . They brought instruments and approaches to observing lakes that were new and difficult. . . . They collected data in these lakes that had never been gathered by anyone with the precision and accuracy that they did."

R. Ragotzkie, 1983, "History of Limnology in Wisconsin Conference."

In the 1920s and 1930s limnological research flourished not only at the University of Wisconsin and Yale, but also at the University of Michigan and the University of Illinois. Limnology was beginning to attract larger numbers of students and in 1936 the Limnological Society of America was organized. Juday was elected its first president, having played a role, albeit somewhat reluctantly, in the formation of the society. He was reelected to the post the following year.

"We had a hydrobiological program at the AAAS meeting in Pittsburgh during the holiday season and had a very good turnout; over a hundred at the meeting. We also decided to organize a Limnological Society of America. It will be launched at the 1935 meeting in St. Louis next December. I am curious to see how many people can be induced to join it. Welch has been wanting to organize for the past three or four years, but some of us have been discouraging him; we decided, however, to let him try it after talking the proposition over at the Pittsburgh meeting."

C. Juday, 1935, letter to S. Wright.

In a mere five years since the formation of the Society, Juday would witness the tremendous growth of interest in limnology, but he remained skeptical that this interest would last.

"Last week I attended the AAAS meetings in Columbus, chiefly those of the limnologists and ecologists. One of the striking things about the limnological sessions was the large attendance, from 100 to 200 at all sessions—most of them youngsters. Limnology is certainly on the boom; everybody is talking about it now and all kinds of colleges and universities are now offering courses in it. I am wondering how long the boom will last."

C. Juday, 1940, letter to S. Wright.

Although the limnological research program at Trout Lake and in Madison survived the Depression relatively well and even flourished during those years, the program began to decline as Birge and Juday grew older. World War II also took its toll.

"Four of us came up June 20 to get things ready for the summer campaign which opened up on July first. . . . I have a crew of five this summer; Dean Fred asked me to reduce our force to a minimum, so I asked for men to help in only two projects, namely, fish population studies and a crew for plankton together with bottom fauna and flora. . . . Counting the wife of one of the boys who is cooking for the crew, we have a total of eight as compared with 21 last year."

C. Juday, 1942, letter to S. Wright.

". . . the Laboratory there [Trout Lake] is going to be one of the war fatalities this coming summer. It is impossible for me to get competent assistants, so I shall not go up to Trout Lake this summer, the first summer I have missed since 1925."

C. Juday, 1943, letter to S. Wright.

Although he had set out to write a comprehensive review of Wisconsin limnology, Juday died March 29, 1944, before he could complete it. He was also unable to finish a number of papers he had hoped to write using the large amounts of unpublished data he and his colleagues had collected at Trout Lake.

"At the present time I am preparing a book on our Wisconsin investigations and it is a tough job to get the stuff all lined up and correlated. I would much rather prepare papers on the great amount of data that we have accumulated during the years and which has not been utilized for papers so far. But that is something to look forward to after the book is completed."

C. Juday, 1943, letter to S. Wright.

Although Birge lived until June 9, 1950, the last paper he published was with Juday in 1941. The two partners had been very similar in some ways, but widely different in others. Despite a professional partnership that lasted more than four decades, the two had not been close friends.

"Birge and Juday were colleagues, but not necessarily friends. Juday was not a social person. . . . Birge and Juday got along well. I think Juday looked up to Birge . . . but Birge and Juday went their separate ways socially. . . . Juday was pleasant, affable, but rather withdrawn. He was not a pusher, but he was a great scientist. . . . Juday was always willing to show you what was going on if you were interested. He was cordial and helpful and liked you as long as you were interested in limnology."

D. Halverson, 1985, personal communication.

Mary Juday, however, notes that the Juday and Birge families often socialized and frequently spent holidays together. She and her older brother, Chancey, called Birge's wife, Anna Grant Birge, "Grandma" (M. Juday, 1987, personal communication).

The two partners varied considerably in their teaching styles. Birge was considered an excellent teacher, who inspired loyalty and admiration. His first bacteriology class included Harry L. Russell, who went on to a distinguished career in bacteriology and to become Dean of the College of Agriculture at the University of Wisconsin.

"As my class advisor, he [Birge] warned against the danger of over-specialization in too narrow a field. He insisted on my taking courses in history under another marvelous teacher in the University, Professor William F. Allen, when I wanted to load my schedule with more courses in science. He wished his students to secure an all-round training, to get the breadth of view that comes only from a broad survey of the various fields of knowldege. The specialist in pursuit of his own particular line digs his canyon of activity deeper and deeper, narrowing his vision more and more until he loses his perspective on the broader problems of life. Dr. Birge belongs to the group that views the world from the mountain top rather than from the canyon depth."

H. Russell, 1940, First Symposium on Hydrobiology.

Martin Gillen, another of Birge's early students, was inspired to create a nature preserve. He purchased 6000 acres including 22 lakes on the boundary between Wisconsin and Michigan's Upper Peninsula "to be guarded from the further scars of the white man's civilization and forever dedicated to the study of the sciences relating to the flora and fauna of our state" (1940, First Symposium on Hydrobiology). When asked how, after a lifetime of activity in legal and industrial affairs, he had become interested in the work of biologists, Gillen responded:

"Thirty-nine years ago [1894], as a young student at the University of Wisconsin, my electives included biology and bacteriology. All this summer [1933 when Birge was 81] I have watched Dr. Birge in dungarees accompanied by 16 or 17 young scientists still exploring the field I once studied, still working to lay the foundation upon which will be based the solution to problems that confront our people, our state, and our nation. I am once again his student and helper and there is much to be done."

M. Gillen, 1940, as quoted by General Ralph Immell
at the First Symposium of Hydrobiology.

Unlike Birge, Juday is not remembered for his teaching skills or inspiring lectures. Although his former students have the highest regard for his knowledge of limnology and his skill as a researcher, they recalled that his courses in limnology and plankton organisms were "just deadly."

Whereas Juday had been known as mild-mannered, quiet, and withdrawn, Birge was renowned for his caustic comments and astringent wit. He was not so much beloved by his students as respected and admired.

Birge was concerned for his students' training, but he seemed relatively unconcerned about their general welfare. According to the story related by E. Schneberger (1983, personal communication), one of Bernhard Domogalla's tasks while he was working as a student assistant for Birge in Madison was to take water temperatures in Lake Mendota throughout the year. One spring when the ice was getting thin and "black," Birge asked Domogalla to take the water temperature with the Whitney thermometer, but added, "if you start going through, throw the thermometer toward shore—it's the only one we have."

Birge must have had his tender side, however, even though it was rarely seen. While Schneberger was at the Trout Lake Station, his wife, Helen, who was the "camp cook" in 1932, and his young daughter, Wilma Jean, came with him in the summers of 1930 to 1934. Birge always remembered to write a letter and get a present for Wilma Jean on her birthday (H. Schneberger 1983, personal communication).

Both men were relatively distant and taciturn. Neither had much use for small talk, which was not so much the result of rudeness, but rather the inability to make conversation upon any topic but an important one. Juday seemed to be completely devoted to limnology and spent nearly every waking moment working.

> "Father used to work a seven-day week including evenings and Sundays. . . . He was definitely a 'workaholic.' He had virtually no outside interests. He didn't read books for pleasure. He didn't go to movies or any of that stuff. . . . Mother was much more outgoing. . . . They always got along well I think. She felt her role was to make it easy for him to do what he wanted. So she took charge of raising us. Father was rather remote I'd say. He was around, but he didn't take any great interest in what was going on. . . . I never worked with Dad, I never learned zooplankton, which was his speciality. . . . He did not discuss his work with us."
>
> R. Juday, 1983, "History of Limnology in Wisconsin Conference."

Birge was certainly hard-driving, but unlike Juday, he was a man of wide-ranging interests and a voracious reader of philosophy, history, religion, and novels, as well as science. The rumor was that he served on the City Library Board in Madison just so he could read the new books before they went on the shelves. He was also known as a religious man. He regularly attended the First Congregational Church where he taught an adult class and gave annual sermons on St. Paul at the Grace Episcopal Church. His religious beliefs, his scientific views, and his considerations of literature seemed to have been integrated into a coherent philosophy of life.

> ". . . something must be done in the right way and this is true of religion just as it is of those other things. It is true that if you practise the violin in the right way, the instrument finally talks to you and you to it. It is also true that you may practice scales till you die and never find music—only technique. And of course the same is true of religion. That is why St. Paul says, 'Walk by faith' not merely 'Walk.' And it isn't easy to say what this necessary faith is in this connection or indeed in any other. How must you study Latin grammar so as to get on the inside of Latin literature? If you do it in the right way the result comes—certainly and, as you see afterwards, inevitably. If done in the wrong way—grudgingly or of necessity or 'for marks' or in many other ways—nothing results that is worthwhile. So of science—work may result in technique and nothing more if it is done in that spirit. . . . And the thing must be done simply and in a way for its own sake—not 'to be seen of man' . . . or for any other reward. Especially you mustn't be looking for a revelation of music or science or religion or of God in any similar relation. If you do the revelation isn't likely to come."
>
> E. A. Birge, 1925, in a letter to Mrs. Peckham, widow of well-known biologist, George W. Peckham of Milwaukee, as quoted by Sellery (1956).

Birge and Juday form an outstanding example of the value of partnership. Their ability to work together despite their differences, the strength of their personalities, and their intense interest in lakes shaped the growth and development of limnology not only in Wisconsin, but in North America and Europe as well. But they had chosen no successor and the Wisconsin school declined for some years before another strong leader, Arthur D. Hasler, took over and led the Wisconsin limnological school in an entirely new direction.

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3 New Directions

Under the leadership of Arthur Davis Hasler, limnological research at the University of Wisconsin shifted away from the classical, descriptive studies conducted by Birge and Juday, toward the new field of experimental limnology, in which the precise methods of the experimental laboratory were applied to research in the field.

> "I could see that it was presumptuous to try to make a reputation by following in the Birge and Juday research tradition. Moreover, you couldn't get money for that type of research— recording the environment. . . . Besides, my research interests were in a different direction—experiments in the natural environment."
>
> A. D. Hasler, 1985, personal communication.

Hasler and his students were among the first limnologists to do field experiments that included controls and repetitions. Moreover, they improved the experimental techniques used in the field. Under Hasler's leadership, rigorous experimental methodology became the hallmark of the Wisconsin limnological school.

> "Experimental work was done in Germany at the turn of the century with fertilizers and carp ponds. And the Chinese did it before that. So experimental limnology is not a tradition which started here. . . .
>
> "We all ask who was the first to do something. It's usually pretty hard to say. What we did was to refine experiments and equipment, to improve upon them. . . . We were not necessarily the first to do things, but we were perhaps the first to 'do them right.' "
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler spent much of his career trying to show skeptical laboratory scientists that rigorous experiments could be conducted outdoors.

> "Having been raised in a department of molecular biologists and cytologists, it's been quite a chore to justify being an experimental scientist to them. I believe that the average laboratory biologist just can't quite conceive that outdoor research can be done in a rigorous way. We've always had a battle to convince them that what we were doing experimentally was legitimate. They think we're at Trout Lake fishing or sunning ourselves."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

In the course of their research, Hasler and his associates not only became far more experimental than Birge and Juday, they also came to view lakes in a different way. Birge and Juday saw the lake as a microcosm, a unit of the environment. Hasler and his associates began to give much greater consideration to the watershed.

> "We've emphasized the fact that lakes are mirror images of the landscape around them. . . . This stems from my collaboration with Wisconsin botanists, especially ecological botanists like Fassett and Curtis. They taught me early how a lake is influenced by what drains into it. . . . I think my ideas about salmon homing stem from that, the fact that the vegetation and the soils

lend to the river a quality of odor that makes it unique. No two rivers are alike. So this whole idea of interactions between land and water is something we emphasize.''

A. D. Hasler, 1983, ''History of Limnology in Wisconsin Conference.''

Hasler [b. 1908] had grown up in Utah—a state not known for extensive limnological resources. He attended Brigham Young University as an undergraduate.

''My father was a physician and his plan was for my brother, who was in medical school, and me—that the three of us should set up a clinic when I got through too. But the Depression occurred at that time and my father was stricken with cancer, which took him out of practice for several years. So the financial structure of the family fell apart. In those days you couldn't borrow money to go to medical school so it meant that I had to find some alternative to medicine. . . . That was my junior year of college.''

A. D. Hasler, 1983, ''History of Limnology in Wisconsin Conference.''

During his junior year at Brigham Young, Hasler accompanied one of his professors on a research expedition to the Granddaddy Lakes in the Uinta Mountains and soon became interested in limnology. Unable to pursue a career in medicine, he entered graduate school at the University of Wisconsin in 1932. His major professor was Chancey Juday.

''When I first began to think about being a limnologist I wrote several letters, one to A. S. Pearse, a former professor of zoology at Wisconsin, but then at Duke University. He had written a book on ecology and I wrote him asking what a young man ought to do to prepare himself. His answer was 'first become a physiologist and then become an ecologist.' So I came to Wisconsin and that's just exactly what Juday did for me—he requested that I get my minor in physiological chemistry and physiology. So obviously it was the concept of the time—to get students trained in experimental thinking.''

A. D. Hasler, 1983, ''History of Limnology in Wisconsin Conference.''

For his thesis research Hasler worked on the digestive enzymes of copepods and cladocerans (Hasler 1935, 1937) with H. C. Bradley in the Department of Physiological Chemistry. The experiments, most of which were carried out at the Wood's Hole laboratory in Massachusetts, were conducted with controls and repetitions. His experience with controlled experiments made Hasler aware of the deficiencies in the field ''experiments'' conducted at the Trout Lake Station when he worked with Juday during the summers of 1933 and 1934.

''I was here in 1934 when Weber Lake was being fertilized with a sequence of chemicals. One year it was soybean meal, another year it was phosphorus, another year it was lime. I was part of the team putting the chemicals in for that series of tests. I won't call them experiments. When you think about what was known of experimentation at the time—principally owing to R. A. Fisher, who had written a book on biometry and design of experiments for agriculture plots—the Weber study couldn't qualify as an experiment.

''One of the benefits of working as an assistant to Juday, however, was learning how to do scientific work outdoors, how to work in the field. And it was valuable experience going from lake to lake to see the variability.''

A. D. Hasler, 1983, ''History of Limnology in Wisconsin Conference.''

Hasler's first experience with manipulating animals under controlled conditions in the field came early in his career. Before he had completed his Ph.D. thesis, he was hired by the United States Bureau of Fisheries to work on Chesapeake Bay in Yorktown, Virginia. He was to conduct field experiments on the effects on oysters of effluents from paper pulp mills (Hasler *et al.,* 1938, Hasler *et al.,* 1947). Hasler worked as an assistant biologist for the U.S. Bureau of Fisheries from 1935 to 1937.

After completing his doctoral degree, he was asked to return to the University of Wisconsin in 1937 as an instructor in the Zoology Department. He had been invited back to Wisconsin not by Birge or Juday, but by Michael F. Guyer, who was then Chairman of the Zoology Department. Birge and Juday were approaching retirement and Guyer's intent was for Hasler to take over their duties. These arrangements had been made without consulting Birge and Juday, however (Hasler 1979, personal communication).

> "Birge and Guyer were antagonists. Guyer came into zoology [from the University of Cincinnati in 1911] with the understanding that Birge would have nothing to do with his program. He [Guyer] built that little lab [1933] at the end of Park Street [on Lake Mendota] and he wouldn't allow either Birge or Juday to set foot in that lab. . . . Who brought me into zoology? Not Birge or Juday, but Guyer."
>
> A. D. Hasler, 1983 "History of Limnology in Wisconsin Conference."

Hasler had never been well acquainted with Birge, who was already 81 when Hasler first came to Wisconsin, and he has always felt that Birge viewed him as a young upstart. (Hasler 1979, personal communication). Neither Birge nor Juday invited him to use their facilities on Trout Lake, but he was assigned to Guyer's new boat house on Lake Mendota. The basement provided boats and space for aquaria, and the room above had apparatus and desks for students. A Quonset hut near the lake lab was made available for aquaria about 1950.

Shortly after returning to Wisconsin, Hasler, in cooperation with Roland K. Meyer, began conducting physiological research on fish. They were among the first biologists in North America to study fish endocrinology in their investigations of the use of pituitary extracts for inducing premature spawning in trout and muskellunge (Hasler, Meyer, and Field 1939, 1940). Hasler and Meyer (1942) also investigated the respiratory responses of normal and castrated goldfish to fish and mammalian hormones. During this time Hasler was also conducting field research on fish in Crater Lake, Oregon (Hasler 1938, Hasler and Farner 1942), and in Lake Mendota, and spent two summers teaching and conducting research at the Lake Geneva School of Science in southeastern Wisconsin (Hasler and Nelson 1942).

When Juday retired in 1941, Hasler took over the course work and research area for which Juday had been responsible, but supervision of the Trout Lake Station went to Lowell Noland of the Zoology Department in 1942, and then later to other university faculty. Hasler would not become director of the Trout Lake Station until 1962, the year he built the Limnology Laboratory on Lake Mendota.

> "There were advantages to my not being appointed director of the station earlier. I might have gotten stuck in the Birge-Juday research tradition. As it was, I was able to start in my own direction early. I got into the salmon work on the west coast, which I might not have had I been confined to the station."
>
> A. D. Hasler, 1979, personal communication.

World War II disrupted limnological research in Madison and at Trout Lake, as it did elsewhere. During the spring and summer of 1945 Hasler served with the United States Air Force Strategic Bombing Survey in Germany. After the war's end, he was able to visit a number of biological stations and laboratories in England, Germany, and Austria. He met animal ecologist Charles Elton at the Bureau of Animal Populations in Oxford, England, fish physiologist Werner Jacobs of the Zoologisches Institut at the University of Munich, alpine limnologist and ecologist Professor Otto Steinbock at the University of Innsbruck, and the director of the Reichsanstalt für Fisherel Weissenbach, Dr. W. Einsele, who in 1939 and 1940 had been conducting experiments adding phosphorus to lakes near the Bodensee.

Hasler also met his "scientific hero," Professor Karl von Frisch, a man he had admired for several years "because of his outstanding research on the sensory abilities of fish, bees, and other animals" (Hasler 1945). Von Firsch recalled his first meeting with Hasler in his autobiography.

> "The first days of the occupation were full of incident and excitement. There were innumerable strict rules, and quite often our homes were being searched by soldiers with rifles at the ready. We lived in constant fear that the military might requisition our houses for the troops. So when one fine day in June an American jeep with four officers stopped in front of our home, we were not a little worried. However, the man who got out first did not inquire about billets but asked after me and my honey-bees. My wife directed him to the observation hives, and there, for the time being, he remained. He was Professor A. D. Hasler, biologist at the University of Wisconsin, who was staying in Salzburg to investigate war damage. . . . Hasler came often to our house that summer, we became fast friends, and later visited each other in our laboratories."
>
> K. von Frisch, 1967, *A Biologist Remembers.*

In his reports on the post-war conditions of European biological stations, Hasler described the devastation the war had brought to so many laboratories and research facilities including those of von Frisch.

> "The director of the Zoologisches Institut [University of Munich], Professor von Frisch, was forced to move to his summer cottage near Salzburg when his residence in Munich was completely destroyed. Because he thought the Munich residential area would not be bombed he had moved his library to his home. Thus one of the finest libraries in sensory physiology was blown up. . . . He has worked extensively on sense of smell, color changes in fish and was the discoverer of 'Schreckstoff,' a secretion from injured skin of *Phoxinus* which, in extremely small concentrations, is perceived by schools of this minnow who are alarmed and seek cover."
>
> A. D. Hasler, 1945, "A War Time View of European Biological Stations."

Hasler would visit with von Frisch again in 1954 when, on a Fulbright Research Scholarship, he returned to Germany with his wife Hanna and their six children. During that year Hasler also met the German animal behaviorist Konrad Lorenz. Hasler's own ideas on fish homing behavior would be greatly influenced by Lorenz's studies of imprinting—the process of rapid and irreversible learning during a critical period of development that generally elicits a stereotyped pattern of behavior.

With his background in physiology, and inspired by his many discussions with von Frisch, Hasler, with his students, began research on the sensory physiology of fish when he returned to Madison in 1945.

> ". . . a returning veteran, T. J. Walker expressed interest in olfactory physiology of fish and re-

quested a Ph.D. research topic. Having become interested in macrophytes through Prof. N. C. Fassett (Botany) and the research of another graduate student of mine, J. D. Andrews, I suggested to Walker that we test the ability of fish to distinguish aquatic plants by smell. I reasoned there might be some interaction between fish and macrophytes—after all, they lay their eggs on them, eat insect larvae living on them, and find cover among them from predators."

A. D. Hasler, 1983, personal communication.

About this same time Hasler became fascinated with the mystery of how salmon find their way from the open ocean to their natal stream to spawn. The combination of his fascination with salmon homing, his interest in Lorenz's recent studies of imprinting, and his and his students' research on the abilities of fish to discriminate plants by odor led Hasler and his student, Warren Wisby, to develop a hypothesis about salmon homing. The olfactory hypothesis for salmon homing, first presented by Hasler and Wisby in 1951, had three basic tenets: 1) because of local differences in soil and vegetation of the drainage basin, each stream has a unique chemical composition and thus, a distinctive odor; 2) before juvenile salmon migrate to the sea they become imprinted to the distinctive odor of their home stream; and 3) adult salmon use this information as a clue for homing when they migrate through the home stream network to the home tributary (Hasler and Scholz 1983). The story of the research on salmon homing and orientation conducted by Hasler and his associates is told in greater detail in Chapter 5.

Research on salmon homing and orientation became Hasler's life work and the research for which he became best known. With his graduate students and associates, he spent the better part of 35 years testing the olfactory hypothesis of salmon homing. The list of students and collaborators in the homing research includes Warren J. Wisby, Ross M. Horrall, Andrew E. Dizon, Aivars B. Stasko, Dale M. Madison, Jon C. Cooper, Peter Hirsch, Peter B. Johnsen, and Allan T. Scholz. Hasler drew together the various studies on fish homing behavior in 1966 for *Underwater Guideposts* and again in 1983 for *Olfactory Imprinting and Homing in the Salmon,* the latter written in collaboration with his student, Allan Scholz.

The olfactory homing hypothesis explained how salmon recognize their home stream, but it could not explain their movements in the open sea. In a series of field and laboratory tests conducted from 1955 through 1971, Hasler and his associates, Horrall, Wisby, Wolfgang Braemer, Horst Schwassmann, E. S. Gardella, H. F. Henderson, and Gerald Chipman, demonstrated that a number of fish species possess a sun-compass mechanism and that they can orient by the sun to maintain a constant compass direction in unfamiliar territory.

"Here again Karl von Frisch, who discovered this [sun-compass orientation] in bees, and Gustav Kramer in Germany, who discovered it independently in birds, were sources of inspiration. Our contribution lay not in the concept, but in the methodology of demonstrating how fish use sun-compass orientation."

A. D. Hasler, 1983, personal communication.

The first major funding for the salmon research came from the Office of Naval Research (ONR). After the war the Navy also supplied Hasler and his students with sophisticated equipment.

"George Sprugel, research coordinator for ONR, heard my research report at a national scientific meeting on the sense of smell of fishes and orientation, held about 1947. He invited me to write a research proposal to finance the beginning of our studies on salmon. . . .

> "From the contacts we had with the ONR, they provided us with these expensive instruments free-of-charge. You couldn't buy them on the market or at least you didn't have enough money to buy them on the market. . . . Because of our connections with ONR, all kinds of surplus navy equipment became available after the war . . . including sonar for recording pelagic fish and doing bathymetric maps of lakes, underwater sound recorders for listening to fish 'voices', a motor launch, jeeps and ultrasonic transducers."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Although perhaps best known in scientific circles for his research on salmon homing, Hasler and his students were also involved in a great many other research areas. From the very beginning of his career Hasler had been influenced by the work of R. A. Fisher, and he encouraged his students to study statistics. Two of his early students, John Neess and Richard Parker, minored in statistics. Hasler and his students began applying "R. A. Fisher criteria" to field experiments.

> "When R. A. Fisher applied the methods of biometry to the design of experiments on agricultural field plots, and their evaluation through multiple correlations, he performed an invaluable service to biology. In doing so, he broke with the traditions of experimentation, which had been imposed by the exact sciences—namely, the manipulation, during an experimental series, of only one factor at a time."
>
> A. D. Hasler, 1964, "Experimental Limnology."

Hasler's first graduate students, Jay D. Andrews (1944), Elizabeth Jones (1947), and John C. Neess (1949), constructed experimental ponds for studies of interactions among macrophytes and plankton, and in Neess' project, fish and macrophytes. Although Neess' study got off to a rough start, eventually it was successfully completed.

> "Four ponds were dug in the Gardner Marsh [University of Wisconsin Arboretum] for use by John Neess in his Ph.D. thesis project. The initial attempt to dig the ponds with explosions of dynamite failed. The force impelled the peat straight in the air and it cascaded right back again. This feat became known in Arboretum circles as 'Hasler's Folly.' "
>
> A. D. Hasler, 1983, personal communication.

The desire to simulate more natural conditions than experimental ponds soon led Hasler to perform the "whole lake manipulations" for which he became so well known. Many of the ideas and techniques for these studies grew out of the interdepartmental communication Hasler fostered throughout his career.

> "The monthly meetings of the Graduate Biological Division provided occasions to meet senior colleagues campus wide. . . . At one of the meetings I conversed with Bob Muckenhirn about our brown-water and acid bog lakes. He introduced me to Prof. Emil Truog who had studied the chemistry of bog soils. He had observed that the drainage of these limed soils became clear, and hence allowed that we might clear up our bog lake with calcium hydroxide, $Ca(OH)_2$. [Some scientists had already tried calcium carbonate, $CaCO_3$, which did not work because it is insoluble in lake water.] Laboratory studies confirmed this hunch, hence we could then try to alkalize a whole lake, which we did experimentally in Cather, and later in the twin lakes, Peter and Paul."
>
> A. D. Hasler, 1983, personal communication.

The Cather Lake study was a "before and after" experiment. That is, William Helm, a student of Hasler, investigated the limnological characteristics of Cather Lake for two years, and then commercial hydrated lime ($Ca(OH)_2$) was added. But Hasler was not entirely satisfied with the rigor of this type of experiment.

> "When you go to bigger things than ponds—dealing with larger units and manipulation—you get into a great deal of difficulty. There, rigorous experiments are much more difficult to accomplish and you have to make modifications or concessions about rigorous research when you deal with large bodies.
>
> "The concession we made with Bill Helm's program [Cather Lake], when we were trying to reduce the bog colloids in the lakes by lime treatment (calcium hydroxide), was that we chose to study the plankton and fish populations for two years and then have two years of treatment, so that we had a before and after type experiment. The weakness is that you don't know whether some natural events might have caused the change rather that the lime you put in.
>
> "Then I learned from John Curtis [Botany] about the lakes up at the Notre Dame property, the former Gillen Estate. I had told John that I needed to go one step closer to rigorous and he told me that there was a lake there that had a constriction in it. Now we had a lake that we could divide by a barrier so that we could have a reference lake and an experimental one—I don't call it control, but reference, because unless they're identical in their size, volume, and so forth, you can't use the word control. We upgraded the rigor of the before and after design by the Peter and Paul situation."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

Hasler's students, Waldo E. Johnson and Ray Stross, conducted research using the two halves of the hourglass-shaped lake. Both projects, as well as the Cather Lake study, are discussed in Chapter 5. Johnson was later hired by the Canadian government where he worked his way up in the administration of water management.

> "Johnson was instrumental in convincing the Canadian government to set aside a vast area of twenty-odd lakes in Manitoba for experimental research. Obviously his training in Wisconsin on Peter and Paul Lakes gave him this motivation. . . .
>
> "It was in one of these Canadian lakes that a very crucial experiment on eutrophication took place. Using the same technique we used on Peter and Paul, they divided a lake with an artificial barrier and put phosphates on one side and left the other side as a reference. They showed that you could develop a eutrophic lake. Then when they stopped fertilizing it, the lake became normal again. So these two experimental lakes in the 70s were definitive tests of the eutrophication hypothesis. All over the country, people, especially engineers, had doubted that phosphorus was the critical element in eutrophication. . . . So I'm proud of the contribution the Peter and Paul experiment made on the North American scene."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

These were the days before the National Science Foundation and large-scale government funding for research. Hasler obtained the money for the lake manipulation studies by contacting the owners of small lakes and getting their support. Many of these projects could not have been done on public lands because of legal restrictions or public interference. Some of the lake-shore property owners, such as Guido Rahr, Ben McGiveran, and Stib Stewart, made substantial contributions to the university to support the projects. In several instances four-year research assistantships were established by private donors, thus enabling several graduate students to gather data for master's or doctoral theses. The grants were rarely ample, however. The conditions under which students conducted field research had not improved much since the Depression of the

1930s. William Schmitz, a student of Hasler, recalled the conditions he found when he took over the Cather Lake project.

> "I remember the first night when I was given the task of taking over the research in Chippewa County [Cather Lake]. I think we'd been married for two years—I still called her my bride. It was on a June night that we drove down the hill to the converted chicken shack, a Quonset hut made of plywood. We opened the door and she looked in there and she was starting to feel pretty apprehensive. There was no electricity. There was no light at all, other than the headlights on the truck. The air was so thick with mosquitos in the month of June that you could hardly breathe. We went in and moved all this junk. . . . We had to move the boats and the paint buckets, the anchors and the rope, the poles, and the weed collections to clear a path to the bunkbed.
>
> "During the night she heard crawling and moving. I shined the flashlight over on the table. The deermice had taken up residence in the desk, where they were eating creel cards and chemical records, and also nursing their young. The bats were fluttering in between the ceiling. The poor woman was beside herself.
>
> "All the things that had to be kept cold, I kept in the hypolimnion in a basket. It smelled like rotten eggs once you got the package open even though everything was alright. She left after about a week, so I spent the next three summers pretty much alone."
>
> W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

Many lake-shore property owners gave money to the limnology program because they felt the research might have practical applications, such as making bog lakes suitable for trout; they could also get a tax deduction by giving money for research.

> "We used applied aspects of research to get money, but what we were really interested in were hypotheses and ideas about lakes."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

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4 Expansion

With the establishment of the National Science Foundation (1950) and the Atomic Energy Commission (1946), the era of "big money" in science began and Hasler was on the ground floor. Early in his career Hasler became a "grant getter," a person who could get the money that would allow other people to carry out the research. From these new funding agencies, he was able to obtain substantial monies for his research and for the construction of a new laboratory on Lake Mendota in 1962. He was also fortunate to be in a state where there was strong interest in conservation. Cooperation between the state of Wisconsin and the university allowed Hasler and his students to have access to state resources, primarily through the Conservation Department (now the Department of Natural Resources).

> "Hasler made a conscious decision early on. He could do his own research or get into biopolitics—grantsmanship—and have lots of graduate students. He made the decision to be associated with biopolitics. Hasler recognized early what his strengths were—he could get money to provide the setting for other people to do research.
>
> "He was the right man at the right time. Right after Sputnik, there was a big push for science. Money was available everywhere. Hasler had one of the few programs in the country that had shown progress. The salmon experiments and the research on Peter and Paul Lakes were well known. . . . He devoted himself full-time to getting funds. Hasler saw the opportunity and he took it."
>
> C. Voightlander, 1983, personal communication.

Although many of his graduate students and colleagues feel that Hasler had a "grand scheme" for the Wisconsin limnological school and that grant-getting was a part of that scheme, Hasler recalls his past actions as being less well-planned.

> "There was a lot of opportunism in my activities—opportunism and ambition—rather than long-range planning. . . . I just like working with more than one thing at a time. I enjoy multiple activities and a variety of personalities."
>
> A. D. Hasler, 1985, personal communication.

In addition to money, Hasler also had lots of good, innovative ideas. The ideas and the availability of funds attracted top-notch graduate students, who had good research ideas of their own. Hasler soon had a large number of students involved in a broad range of research topics. In his pet area, salmon homing and orientation, he called the shots. But otherwise, he was not intimately involved in his students' research. Like Birge and Juday, Hasler expected students to be independent and develop their own ideas, and he gave students the freedom to make their own decisions.

> "Students had to be independent to survive. The lake lab was no place for someone who was dependent. . . . Students had to define their own projects, their own line of inquiry, preferably in a proposal on paper, then Hasler approved the ideas. Hasler was hard-nosed about research, but he allowed a great deal of latitude."
>
> C. Voightlander, 1983, personal communication.

Hasler's favorite quote comes from Louis Pasteur, "Chance favors only the prepared mind." Hasler tried to create an environment in which both he and his students could take advantage of serendipity. He felt that the best preparation for the generation of good ideas for research was to be in a stimulating environment.

> "New and challenging ideas for research were the principal features which attracted money, equipment, collaborators, and graduate students into the limnology program. . . . I tell my students to discuss their ideas with others and not to be afraid if an idea is stolen. You don't belong in science if you have so few ideas you fear having one stolen. You get ideas by discussing them. Hence you gain more than you lose."
>
> A. D. Hasler, 1983, personal communication.

Hasler established a program to bring in eminent scientists and, unlike Birge and Juday, he made a point of introducing them to the graduate students. Through his research grants, he kept a flow into the lab of well-known people from around the world. These scientists commonly brought with them new ideas and experimental methods.

> "We had talent from all over the world coming in and I'm sure we picked up ideas and sharpened our own. We had a policy of taking a visitor who was going to be there for a week and sitting him down with every graduate student without our presence. The student could sharpen his ideas against another bright guy."
>
> A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

The environment Hasler provided—innovative ideas, talented graduate and postdoctoral students, interdepartmental collaboration, and visiting scientists from around the country and the world—sparked the generation of new ideas.

> "The resources for advanced graduate students were ideal—lots of technical help as well as intellectual stimulation. . . . There was also a tradition of excellence that one felt must be continued—one occasionally felt that Birge and Juday were watching. . . .
>
> "New graduate students were inundated with ideas from other graduate students. . . . Most of the research ideas came from other students. . . . All of this, of course, subject to the approval and modification by ADH—and the constant scrutiny and 'constructive criticism' by other students."
>
> C. Voightlander, 1983, personal communication.

Hasler's graduate students commonly took their research problems, especially problems in experimental design and statistics to Hasler's former student, John C. Neess, who joined the Zoology Department after completing his Ph.D. degree in 1949. Within the first couple years as a faculty member, Neess separated from Hasler and the limnology lab because he did not want to be thought of as Hasler's successor (Neess 1983, personal communication). He continued, however, to advise Hasler's students.

> "John Neess was a person who was a friend as well as advisor. . . . When we would have difficulties we would go to John, particularly on things like sampling and statistical analysis. . . . John's habit of being available was a tremendous resource for us because you could catch him almost any time. How he got his own work done I don't know. We were always after him for help and he gave it willingly."
>
> W. Helm, 1983, "History of Limnology in Wisconsin Conference."

Hasler's students formed a congenial and mutually supporting group. For many students, the most influential people in the actual development of research—writing, experimental design, and conceptual development of the problem—were fellow graduate students (Hunter, Voightlander, and Wissing 1983, personal communication). At both formal and "brown bag" seminars, which were often attended by people from the Wisconsin Conservation Department, Hasler's students openly exchanged and challenged research ideas. They also commonly helped each other with their field research.

> "As long as I have been associated with limnology in Madison, neither up here [Trout Lake] nor in Madison, did you get any sense of competition or the withholding of information or guarding of information. People were generous with collaboration."
>
> W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

> "Everybody helped each other. We all got experience doing these different things. . . . Hasler didn't explicitly tell students to help on other projects, but there was peer pressure."
>
> R. Ragotzkie, 1983, personal communication.

Hasler's students were involved in a broad range of research areas, only a few of which are discussed here. One major area of study was the extension of the use of radionuclides in experimental limnology. E. Zicker, K. Berger, and Hasler (1956) first began using isotopes to trace the movements of nutrients, specifically phosphorus, in lakes. They found that radiophosphorus, applied to the surface of the mud, does not diffuse readily into the water in an undisturbed system.

Hasler then proposed using lakes as models of the sea in experiments designed to study the physical-biological transport of nuclides in marine situations.

> "The Office of Naval Research held a conference in the 1950s on marine disposal of radioactive waste. We biologists challenged the disposal in meromictic [thermally and chemically stratified] areas because migratory animals would transport it to surface waters. We simulated this in a meromictic lake in Wisconsin. To have done it at sea would have been too expensive and technically impossible."
>
> A. D. Hasler, 1983, personal communication.

From preliminary studies conducted in a small, chemically stratified lake in northwestern Wisconsin, Hasler and his student, Gene Likens, discovered that dipteran larvae transported measurable quantities of radioiodine from the deep water of the lake to the surface and thence, as pupated flying insects, to the shoreline, indicating that radioactive wastes could be transported to the surface and out of the lake or ocean by animals (Likens and Hasler 1963). Likens and Hasler also used radiosodium to measure the movements of water in a lake during both ice-covered and open-water conditions (Likens and Hasler 1962).

The research conducted by Hasler's students and associates covered almost every aspect of what is considered traditional limnology. Studies, for example, included research on the distribution of cobalt in lakes (Parker and Hasler 1969), heat budgets in Madison lakes (Stewart 1973) and in the Madison River in Yellowstone National Park (Wright and Horrall 1967), airborne litterfall as a source of organic matter in lakes (Gasith and Hasler 1976), the distribution of zooplankton in Lake Mendota (Ragotzkie and Bryson 1953), plankton crustacea in Lake Michigan (McNaught 1966, McNaught and Hasler 1966), invertebrates on aquatic plants (Andrews and Hasler 1942), the population ecology of chironomids (Dugdale 1955), ecology of riffle insects in the Firehole River in Wyoming (Armitage 1958, 1961), caloric values of various invertebrates (Wissing and Hasler 1968, 1971b), and the behavioral ecology of caddisflies (Gallepp 1974a, 1974b, 1976, 1977).

Another contributor to the Wisconsin limnological program was G. A. Rohlich of the Departments of Civil and Environmental Engineering and Water Chemistry. The research of Rohlich and his associates was concerned primarily with the origin and quantities of plant nutrients in the Madison lakes and tributaries (see Hasler 1963).

The Wisconsin school of limnology under Hasler's direction conducted far more research on fish than was customary elsewhere.

> "Neither Birge, Welch, nor Hutchinson emphasized the fish of lakes and rivers. It was one of my goals to correct this neglect. Only in 1982 was a textbook published [Goldman] on limnology that had even a chapter on fish communities."
>
> A. D. Hasler, 1983, personal communication.

The following list of research topics is by no means exhaustive, but it does illustrate the breadth of research on fishes conducted by Hasler and his associates. Many of the early studies, such as those on the movements, distribution, and population ecology of perch (Bardach 1951, Hasler 1945, Hasler and Bardach 1949, Hasler and Villemonte 1953, Hergenrader and Hasler 1965, 1967, 1968), carp (Neess, Helm, and Threinen 1955, 1957), cisco (John 1956, John and Hasler 1956), white bass (Horrall 1961, Voightlander and Wissing 1974, Wright 1968), and yellow bass (Helm 1958, Wright 1968) were conducted in Lake Mendota and Lake Wingra.

Research was not confined to Madison-area lakes, however. There were also studies on the trout introduced into alkalized and nonalkalized lakes in northern Wisconsin (Johnson and Hasler 1954), on alleviating winterkill conditions in northern lakes (Schmitz 1959, Schmitz and Hasler 1958), on the feeding ecology of trout in the Brule River in northern Wisconsin (Hunt 1965), on muskellunge and perch populations (Gammon and Hasler 1965), and on limnetic larval fish in northern Wisconsin lakes (Faber 1967). Hasler's student, Francis Henderson, with limnology technician Gerald Chipman developed an ultrasonic transmitter for use in studies of fish movements (Henderson, Hasler, and Chipman 1966).

Another student, William Helm, was the first to build and use an electroshocker in Wisconsin. In this case, necessity was truly the "mother of invention." Helm had been trying to conduct research on walleye in northern Wisconsin and was frustrated in his efforts to catch them.

> "I tried daytime seining, nighttime seining, nice gravely beaches, woody areas—nothing. I was not getting walleye. So we tried to figure out whether we could trawl. From what I could tell of the bottom, that was not a very good prospect.
>
> "I had read somewhere about boom shockers. We had an old surplus generator sitting in a shed down in Madison, so I grabbed that and had an Arkansas traveler boat brought up here. Between a few things I scrounged in Madison and stuff that I bought at a hardware store up here, I put together a boom shocker to find out whether it would work. And it did. So we regrouped and constructed it well enough that it would work for that fall and then went ahead and shocked. It was, to my knowledge, the first workable boom shocker in the state of Wisconsin. . . .
>
> "All that fall there was a steady procession of people in here to look at that boom shocker to see how it worked, because I was collecting walleye with a very, very low mortality rate. We

were also collecting musky with a low mortality rate, so the musky people came charging over here. During the wintertime I built a real gaudy thing, one that allowed me to vary the electrospacing depending on water hardness, conductivity. . . . It improved the efficiency tremendously."

W. Helm, 1983, "History of Limnology in Wisconsin Conference."

Some students also continued in one of Hasler's original lines of research in fish physiology. James Gammon investigated the conversion of food in young muskellunge (Gammon 1963), Thomas Wissing examined the effects of swimming and food intake on the respiration of young-of-the-year white bass (Wissing and Hasler 1971a), and Calvin Kaya investigated the effect of photoperiod and temperature on the gonads of green sunfish (Kaya and Hasler 1972). S. Chidambaram, in collaboration with zoologist, Roland K. Meyer, conducted research on the effects of brain lesions and ACTH on the blood of bullheads (Hasler, Chidambaram, and Meyer 1973).

In addition to training students to be qualified limnologists, Hasler also trained them to be scientists who would be at home on the sea, in a marine bay, on a saltwater lake, or in a river. He also tried to train his students to be opportunists, to be flexible enough to take advantage of new research opportunities and funding sources when they arise.

"I didn't know a damn thing about atomic energy when we got into the isotope research. I had to learn it. I advise my students to train themselves to be able to change. . . . The best thing you can do in your earliest stages is to give yourself the kind of training that isn't final. Get the basics, so you can tackle anything in a systematic, intelligent way with the curiosity, the motivation, and the inspiration to learn it. . . . I think it's a great shame if anyone starts with any subject in science today with the idea that he's going to be doing that all his life. He's a fool to think he can get away with it."

A. D. Hasler, 1983, "History of Limnology in Wisconsin Conference."

His students were also trained to be able administrators of their own research programs.

"Hasler's goal was to train people capable of directing a laboratory in totality. . . . He always said, 'There's more to this business than rowing around the lake.' And he made sure that students knew how to write grants, run a lab, and deal with the public and the politicians. . . . Graduate students did the grant writing. Hasler was the editorial manager."

C. Voightlander, 1983, personal communication.

Students did get plenty of training in running the limnology lab, because Hasler travelled a great deal and was often absent from the lab. The lab was, for the most part, organized and run on a day-to-day basis by students. There were committees—the boat committee, library committee, and so forth. No one was required to work on Hasler's pet projects, but he did require personal responsibility in managing the lake lab in Madison.

Hasler's training of students ensured that many would find their way into influential research and administrative positions. As previously discussed, Waldo Johnson was instrumental in getting the Canadian government to set aside an experimental lakes area in Manitoba. Robert Ragotzkie is the Director of the Sea Grant Program at the University of Wisconsin. Gene Likens is Director of the Institute of Ecosystem Studies at the New

York Botanical Garden. John Bardach recently retired as Director of the East-West Resource Systems Institute in Hawaii. H. Francis Henderson is in charge of the Fish Stock Evaluation Branch of the Food and Agriculture Organization in Rome. Richard A. Parker is Dean of the Graduate School at Washington State University in Pullman, and Warren Wisby is Associate Dean for the Rosenstiel School of Marine and Atmospheric Science at the University of Miami.

From the 1940s to the late 1950s the Trout Lake Station had been relatively unimportant to the development of the Wisconsin limnological program. With the coming of the second World War and the retirement of Juday in 1941, limnological research at the station had come to a standstill. Not only had Hasler not been invited to use the facilities, but his research interests had been focused on lakes in southeastern Wisconsin. Although some students, including Oscar Brynildson, William Helm, Ray Stross, Waldo Johnson, Gene Likens, and William Schmitz, had been conducting research on several northern Wisconsin lakes, the Trout Lake Station did not serve as a base for the limnologists until the late 1950s. Hasler's students recall that in the 1940s and 1950s there was no great agitation to "get something going" at Trout Lake. The station was viewed as a "rough and ready" place with no good research facilities. There was no modern laboratory there until 1967. The real emphasis was on Lake Mendota in Madison, the liming of bog lakes in northeastern Wisconsin, and the salmon homing and orientation research.

From 1942 through 1955, the Trout Lake Station was used by a variety of researchers other than limnologists, including parasitologist Chester Herrick, plant ecologist John Curtis, and wildlife ecologist Robert Dorney. In 1947 Hasler and some of his graduate students made a brief trip north to take to Madison any equipment that might be useful for research on Lake Mendota (Neess and Le Cren 1983, personal communication). Their trip became quite an expedition.

"The Trout Lake Station had been 'mothballed' soon after the outbreak of the war and had remained unvisited for some while. In the summer of 1947, Art Hasler decided that he would visit it to see that the bathhouse laboratories were still standing and such equipment as was there was still in good shape. Accordingly an expedition was planned. We were to drive up from Madison on one day, spend the night there and return the next. . . . One of the stores in Madison had recently bought a batch of ex-Army 'jungle hammocks' that they were selling off for $5.00 each. Several of us had bought one of these and we thought that we would try them out at Trout Lake.

"The party consisted of Art Hasler, John Neess, John Bardach, Ed Nelson, and David Le Cren. . . . We found the huts still standing and full of miscellaneous apparatus (and junk!) just as they had been left some five years before. Art checked things over and rescued some items to use on Mendota. . . .

"Ed disdained the hammocks (which, considering his weight, was wise) and settled down in his sleeping bag onto the sand. The rest of us chose pairs of pine trees and tied up the ropes of our hammocks. However, the fun then began. The hammocks had fly-sheets over the top of them connected to the hammock proper with mosquito-netting. One had to open a zip, insert one's top half and then leap off the ground and pull one's legs in. This was easier said than done, and most of us promptly ended upside down in the fly-sheet. I believe that Art actually rotated two or three times before coming to rest. It then became apparent that the strings on which the hammocks were suspended had been quietly rotting away while stacked in some damp Army store. There was a succession of loud reports, as under tension, first one and then another gave way under the strain of shaking laughter that had by now afflicted the party. I think that John Neess and David did eventually spend quite restful nights in their hammocks.

The others involuntarily joined Ed on the ground; he by now was cursing us for keeping him awake with our mirth and oaths."

D. Le Cren, 1983, personal communication.

In 1962 Hasler had applied for and obtained funds from the National Science Foundation to build a modern research laboratory on Lake Mendota. He was able to have William Kaeser appointed architect for the building to assure a unique style for the prized lake site. In 1967 he was approached by the university administration to get money for a new laboratory on Trout Lake. With matching funds from the university, the National Science Foundation provided money to build the new research facilities. A few graduate students (Philip Doepke, Daniel Faber, James Gammon, William Helm, William Schmitz) had used the facilities at Trout Lake in the 1950s and 1960s, but research activity did not really pick up there until after the new lab was built.

"When I came up in '57 it was the first contact the limnology group had had with the station since the '40s. . . . There was a little resistance to our using the station at first, but I think it was a matter of guarding territories. . . .

"When I was up here, there was a minimum level of activity—only three people working on projects living over here at the time. . . . We were almost in a vacuum."

W. Helm, 1983, "History of Limnology in Wisconsin Conference."

The Department of Natural Resources owned the land on which the first station had been built. The state wanted the station moved from its original location and offered an 80-acre site on the south shore of South Trout for the new laboratory. William Schmitz, one of Hasler's former students and now a faculty member at the University of Wisconsin-Marathon campus, was appointed Associate Director of the station in 1966. In 1965 he had gone to meetings in Warsaw and visited stations in Austria, Denmark, northern Germany, and Poland to garner ideas for the new laboratory at Trout Lake. Under Schmitz's supervision, the new laboratory was built in 1967. Some of the old wooden buildings that Birge and Juday had used as laboratories were pushed across the ice from the old station on the north shore of South Trout to the new site and used for living quarters and warehouses. Birge and Juday had intended the Trout Lake Station to be a temporary research facility (Juday and Birge 1930). With the building of the new lab, the station became a permanent laboratory and went from being only a summer station to providing facilities for research year-round. Hasler remained Director of the station until 1975 when John J. Magnuson succeeded him.

Hasler continued the tradition of interdisciplinary research begun by Birge and Juday. During the Hasler era, however, the involvement of other departments was more biological and behavioral than chemical and physical. Students took courses and sought advice from Norman Fassett, who was interested in aquatic macrophytes, John Curtis, a plant ecologist, Aldo Leopold, a wildlife ecologist, and James Crow, a population geneticist who coadvised Hasler's student, Ralph Nursall.

"In the late 1940s the students of Hasler, Leopold, and Fassett formed a congenial group even though they were doing different things. . . . The University of Wisconsin was one of the few places that had several ecologists, who were all good and who all worked well together. It was a strong campus. Leopold and Fassett recognized ecology as an important discipline, so there were lots of contacts for graduate students interested in ecology."

J. Neess, 1983, personal communication.

Hasler and his students consulted other faculty in addition to the ecologists. Psychologists were intimately involved in designing the behavioral tests used in experiments on the olfactory, homing, and orientation abilities of fish. Faculty from soil physics and soil chemistry advised with the work on liming bog lakes, and faculty and technicians from mechanical engineering helped design and construct equipment for the limnologists.

> "As far as I'm concerned, the engineering people were of most use to me. I borrowed gas meters for measuring air flow. I consulted with Professor Villemonte, who was very helpful. They weren't helpful entirely out of generosity. They got to go fishing up there [Trout Lake]. Every time I consulted with anybody I usually had to spend a half day fishing with them. I fished with everybody. . . . I fished with good fishermen, bad fishermen, and indifferent fishermen. But you know, it was fun to have done that, because you also had a chance to spend some time with them and you pick their brain and you have an enjoyable time."
>
> W. Schmitz, 1983, "History of Limnology in Wisconsin Conference."

Hasler and his students also sought statistical advice from Arthur Chapman in the Statistics Department in the School of Agriculture. And when computers first came into use, the limnologists sought advice on their application to limnological data.

Interdepartmental cooperation became institutionalized in 1962 when the Graduate School approved as an experimental program the interdepartmental Oceanography and Limnology Graduate Program.

> "In the 1960s several professors across the campus agreed to collaborate in offering a graduate curriculum in O & L. Acknowledging that traditional zoology and botany were too restrictive, especially in the areas of water chemistry, physics, meteorology, geology, geophysics, microbiology and hydrology, our program opened O & L to disciplines other than biology."
>
> A. D. Hasler, 1983, personal communication.

The O & L Program attained full status as a recognized degree program in spring 1969. Participating departments include Bacteriology, Botany, Civil and Environmental Engineering (including Water Chemistry), Geology and Geophysics, Meteorology, the Institute for Environmental Studies, and Zoology.

In 1972, through the efforts of Hasler, Robert Ragotzkie, a former student, and Clifford Mortimer, a limnologist from the University of Wisconsin-Milwaukee, Sea Grant status was granted to the University of Wisconsin system. It was only the sixth Sea Grant College in the nation and the first in the Midwest. Ragotzkie was appointed Director of the Sea Grant Program, which in Wisconsin stresses applied research on the Great Lakes. In the course of the salmon homing and orientation research, Hasler and his students had conducted extensive experiments on Lake Michigan, but the Sea Grant Program expanded the scope of Great Lakes research, as well as the resources available to the Wisconsin limnological school.

Even though Hasler and his students were well-funded, the rapid growth of Wisconsin's limnology program from the 1950s to the 1970s still made substantial financial demands on the Zoology Department of which it was a part. Like any leader of a strong research program, Hasler generated some ill-will among a few of his colleagues through competition for departmental funds. He and his students in the lake lab were also isolated from the rest of the Zoology Department, so at times there was a lack of communication between the limnologists and the other zoologists.

"Art wanted the limnology program self-contained and he tried to run the limnology lab as a separate institution. He didn't like being just a faculty member within a department. He went outside the department [to university deans] to get influence, which was irritating to other departmental faculty. Hasler thought the only claim to fame that zoology had was the limnology program—an attitude that tended to irritate other members of the department."

J. Neess, 1983, personal communication.

The intradepartmental conflicts Hasler had with other zoology faculty were, however, relatively minor. Hasler served three years as Chairman of the department, having been elected by a majority vote of the Zoology staff and appointed by the Dean of Letters and Science. And, the rivalries did not affect his students.

"Once he made a commitment to a student, he would back you to the hilt, especially in departmental conflicts. Conflicts did not filter down to affect students. There were certain people you avoided on your committees. Hasler shielded his students from his antagonists in the Zoology Department. It was not an overwhelming problem for us. The students were not penalized."

T. Wissing, 1983, personal communication.

Unlike Birge and Juday, who had remained socially aloof from their students and were uninvolved in their personal lives, Hasler made strong efforts to reduce the social distance between him and his students and among the students themselves. He often entertained students in his home.

"I first met Hasler in September, 1943. He was not like Birge. Hasler was a good person to have as a friend. You could depend on him for personal support."

J. Neess, 1983, personal communication.

Hasler's wife Hanna held regular monthly meetings of the "Fish Wives," a group composed of graduate students' wives.

"Hanna Hasler's meetings of the wives were important. They provided support for the graduate students through the wives. The Haslers' always gave gifts to the wives when their husbands graduated. . . . There's a feeling of closeness among the graduate students that continues 20 years later."

D. Faber, 1983, personal communication.

The Haslers' efforts at providing personal support as well as academic and financial support for students may have stemmed from values learned early. Both Hasler and his wife had been brought up as Mormons where they learned a strong sense of community.

"Being raised a Mormon played a big role in shaping my values. I learned to be a team worker, learned public speaking, and how to conduct meetings. . . .

"As a scientist, one has difficulties. . . . I could have said, 'to hell with my church, I'm just going to quit and not have anything to do with religion.' But then, how am I going to teach my children and other young people I deal with how a scientist thinks? One thing I took on was evolution. I used to give lessons at our church on evolution. The church doesn't accept it at all, but I thought our young people ought to be exposed to evolution. And the Mormon church for many years wouldn't let Blacks hold the priesthood. I took this on and gave many talks about the biology of the equality of man and called for a change in policy, which took place about 1980. Of course, many other Mormon intellectuals did as I did. If I'd run away and thrown stones from the outside there wouldn't have been any change. . . . A lot of scientists just pull away from these things and don't help to change society.

> "Theologically, I'm not a good Mormon, but I'll defend them to my dying day. . . . I had five sons and one daughter. My colleagues in the Mormon community in Madison took the children to baseball games and Boy Scout activities, taught them social dancing, and took them on canoe trips when I was away on research trips and committee assignments in Washington. They were surrogate fathers to them. . . . They were also supportive and compassionate during my late wife's illness with cancer. . . .
>
> "As a scientist, it hasn't been easy to be a Mormon. . . . In 1965 I was one of two candidates for a deanship at a large West Coast university. I had been told by a friend that I had the position. But when I was called the next day, I was told I didn't get it because I was a Mormon. In retrospect it was my good fortune, for I could not have done exciting salmon experiments [which led to Hasler's election to the National Academy of Sciences] had I become an administrator."
>
> A. D. Hasler, 1985, personal communication.

Despite his personal interest in students, Hasler did have an authoritarian presence. He was on a first name basis with a graduate student only after that person became a Ph.D. student. Hasler was also known for his insistence on keeping the lake lab neat and clean. Particularly trying to the graduate students were the preparations they had to make in advance of a site visit from the National Science Foundation.

> "Site visits literally involved white-glove inspections with white lab coats. Hasler would have someone behind him taking notes. There would be a flurry of cleaning up. Hasler was very meticulous. The graduate students once even suggested renting a truck for a day to load everything on, so the lab would look neat for the site visit."
>
> C. Voightlander, 1983, personal communication.

As busy as Hasler was with his graduate students and research, he made time for public service. From the time he returned to the University of Wisconsin and taught his first course in limnology in 1938, Hasler was concerned with conservation.

> "In a state with over 5000 lakes it was my view that every drug store clerk should learn the rudiments of limnology. Because limnology was not in the college student's vocabulary in 1938, the course bore the designation *Conservation of Aquatic Resources.*"
>
> A. D. Hasler, 1983, personal communication.

Long before the ecological awareness of the 1960s and 1970s, Hasler worked with politicians and lobbied for legislation to protect Wisconsin's lakes and streams. He even recruited Fritz Albert to make a "propaganda" film, "What's Happening to Our Lakes?" Unlike Birge and Juday, who had avoided controversial issues such as water pollution and were criticized for leaving the polluted Madison lakes to work on the unspoiled lakes in northern Wisconsin, Hasler and his students were often involved in the research and politics of water pollution and resource conservation (Hasler 1938, 1947, 1967, 1969a, 1969b, 1972, 1973).

In 1972, while he was president of the International Association for Ecology, Hasler helped obtain funds for the workshop on Global Ecological Problems, which was sponsored by The Institute of Ecology. One product of this workshop was the book *Man in the Living Environment. A Report on Global Ecological Problems.*

> "I've always taken some pride in having had the opportunity to be a scholar, a teacher, and a public servant. There's been a lot of satisfaction in serving broadly in the community. . . . But I

don't want to pat myself on the back, because public service has also had its rewards. When I served on committees I met people with whom I could discuss research and get new ideas."

A. D. Hasler, 1985, personal communication.

Hasler was also active in professional societies. He was selected by the executive committee of the American Society of Limnology and Oceanography to be the chairman of the 15th International Congress of Limnology held in Madison in 1962. It was the first time the Congress had been held outside Europe. He applied to the National Science Foundation for funds to support the Congress, which included publication of the book *Limnology in North America,* edited by David Frey, a former student of Chancey Juday.

By 1978, when Hasler retired from teaching and directing the limnology lab, he had trained 53 doctoral students and 41 master's degree students and had co-advised many others (listed in appendix). Many of these students "minored" with collaborating colleagues across the campus. Although he became Emeritus Professor in 1978, Hasler continues to write and to remain active in the activities of the limnology lab, and especially in professional societies such as the prestigious National Academy of Sciences to which he was elected in 1969 and the American Academy of Arts and Sciences to which he was elected in 1972 (see Chapter 5).

Unlike Birge and Juday, who had left the limnology program without strong leadership when they retired, Hasler ensured continuation of the program at Wisconsin by bringing in and training new people to take over when he decided to step down. Hasler recommended John J. Magnuson for appointment in 1968. Magnuson had grown up in the Midwest and had obtained bachelor's (1956) and master's (1958) degrees in fisheries from the University of Minnesota and a Ph.D. (1961) in zoology and oceanography from the University of British Columbia. His major professor was Peter Larkin, but he was also advised by C. C. Lindsey and Bill Hoar.

After completing his doctoral degree, Magnuson went from British Columbia to Hawaii where he was the program leader for the tuna behavior and physiology program sponsored by the Bureau of Commercial Fisheries (now part of the National Oceanographic and Atmospheric Administration). Hasler felt that Magnuson's experience as a "blue-water oceanographer" and his strong background in behavior and physiology would help broaden Wisconsin's research program. One of Magnuson's duties was to direct the Trout Lake Station.

"I fell in love with the station and the northern lakes. It fit in with my background and interests. In Hawaii, I had become interested in how tuna respond to vertical environmental gradients. This interest transferred well to lakes in northern Wisconsin where there are vertical gradients in temperature, oxygen, carbon dioxide, and hydrogen sulfide."

J. Magnuson, 1985, personal communication.

Magnuson had been warned by some colleagues not to take the position in Wisconsin, warned that in working with Hasler he would not have the freedom to develop his own research interests. He quickly discovered, however, that the warnings were unfounded.

"I did not want to become Art's successor with his lines of research, and he did not push me in that direction. . . . I found that Hasler was rigid in some ways—when I tried to hang a picture of Birge on my office wall he gave me a lecture about 'false idols.' I also had to attempt to keep my desk clean. But he provided a great deal of freedom where I wanted it. He did not try to control my teaching, research, or use of facilities. . . . We exploited each other in the best sense of the word. My association with Art opened doors for me that might never have been opened."

J. Magnuson, 1985, personal communication.

There has been no abrupt change in the direction of limnological research as there had been between the Birge and Juday era and the Hasler era, and the transition between leaders has been much smoother. Magnuson has gone in his own direction, however.

"We've tried to take the best of both schools (descriptive-comparative and experimental) and incorporate that into our approach. We didn't choose the approach of one school and reject the other. . . . One element that was not exemplified in either era was mathematical or ecosystems theory—the advances in theoretical ecology were not made at Wisconsin. We hope to add a more theoretical approach.

"We also want to encourage tolerance and diversity, and provide an environment where new ideas are welcome, where people are unrestricted by certain directions or avenues. We want to prevent any one faction, discipline, approach, taxon, or whatever from 'winning.' When only one 'wins,' it is everyone's loss."

J. Magnuson, 1985, personal communication.

Shortly after Magnuson's arrival, James Kitchell, a recent graduate of the University of Colorado (Ph.D. 1970), was hired in 1970 in a postdoctoral appointment with the International Biological Program. This program included a major research project on Lake Wingra. Kitchell became a faculty member in the Zoology Department in 1974.

"Kitchell greatly enriched our program with an ecosystems approach to limnology. He exemplifies both the use of hypothesis testing in manipulating ions of natural lakes and extending the results through computer modeling and simulation. He also is a good team player and enjoys crossing the boundary between fundamental ecological studies and their application to significant problems in fisheries management."

J. Magnuson, 1985, personal communication.

The limnological research program at the University of Wisconsin-Madison is also strengthened by contributions from scientists not directly associated with the limnology lab. Thomas D. Brock of the Department of Bacteriology is widely known for his research on thermophilic microorganisms in hot springs (Brock 1978). He and his students and associates have also conducted extensive research on Lake Mendota, particularly on the phytoplankton, zooplankton, and bacteria. These studies, as well as previous research on Lake Mendota conducted by Birge and Juday and their associates, are described and synthesized in *A Eutrophic Lake: Lake Mendota, Wisconsin* (Brock 1985). Other contributors include Robert Ragotzkie, Director of the Sea Grant Program, Stanley Dodson, Jeffrey Baylis, and Marion Meyer of the Zoology Department, Michael Adams and Timothy Allen of the Botany Department, David Armstrong and Anders Andren of the Water Chemistry Department, and Carl Bowser, Mary Anderson, and Clarence Clay of the Geology and Geophysics Department.

On July 1, 1982, Hasler finally gained a long-term goal when, at Magnuson's urging, E. David Cronon, Dean of Letters and Science at the University of Wisconsin, created the Center for Limnology as a separate institution within the university. Magnuson was appointed Director for the Center and Kitchell became Associate Director for the Limnology Laboratory in Madison. Thomas M. Frost, a recent graduate of Dartmouth College (Ph.D. 1978) who had spent two years on a postdoctoral appointment (University of

Colorado) in Venezuela studying tropical limnology, was appointed Associate Director for the Trout Lake Station. Under Magnuson's leadership, the Wisconsin school continues to be known internationally for its contributions to the science of limnology.

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Fig.1. E. A. Birge and C. Juday with plankton trap on Lake Mendota, about 1917. Source: State Historical Society of Wisconsin.

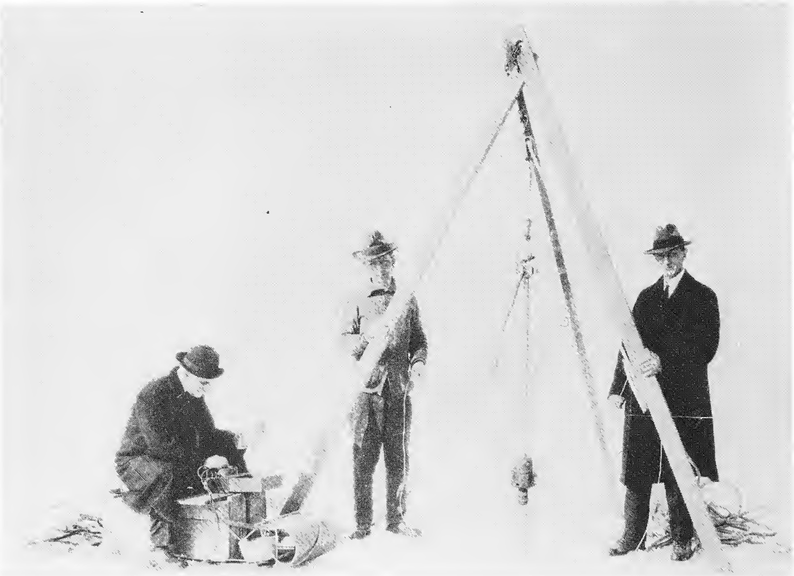

Fig. 2. E. A. Birge, H. W. March, and C. Juday on Lake Mendota with the first mud thermometer, about 1927. Source: State Historical Society of Wisconsin.

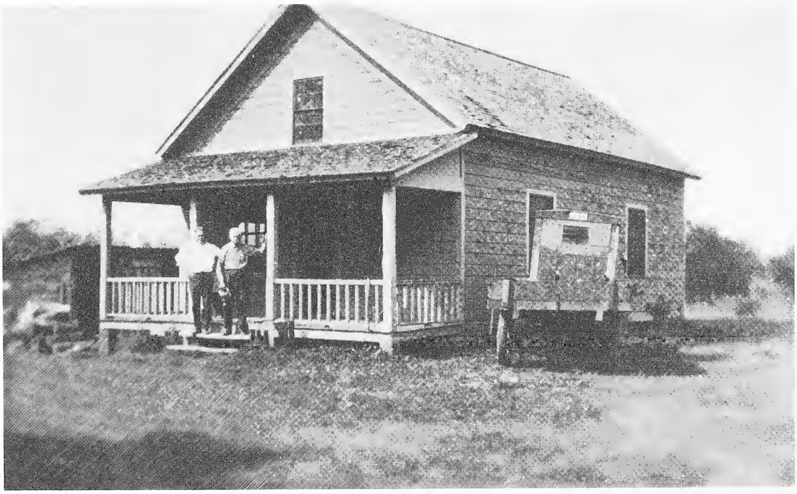

Fig. 3. Stillman Wright and E. A. Birge at the first Trout Lake Station, 1925. Source: Stillman Wright.

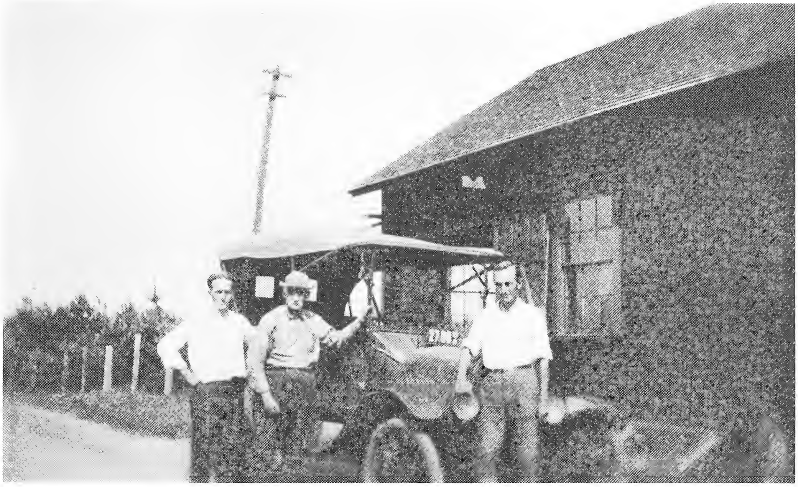

Fig. 4. Stillman Wright, E. A. Birge, and C. Juday at the first Trout Lake Station, 1925. Source: Stillman Wright.

Fig. 5. Fredrick Stare working in the chemistry laboratory at the Trout Lake Station, 1929. Source: State Historical Society of Wisconsin.

Fig. 6. E. A. Birge and C. Juday, 1930. Source: State Historical Society of Wisconsin.

Fig. 7. E. A. Birge with the "sun machine" (on top of car) on Crystal Lake in northern Wisconsin, about 1930. Source: State Historical Society of Wisconsin.

Fig. 8. E. A. Birge and Hugo Baum making observations with the "sun machine," about 1933. Source: State Historical Society of Wisconsin.

Fig. 9. Hugo Baum and A. D. Hasler building lime floats at the Trout Lake Station, 1933. Source: State Historical Society of Wisconsin.

Fig. 10. C. Juday, Villiers (Mel) Meloche, Edward Schneberger, and William Spoor at the Trout Lake Station, 1933. Source: State Historical Society of Wisconsin.

Fig. 11. The Trout Lake Crew in the summer of 1933. Back row (L to R): V. W. Meloche, L. R. Wilson, Ray Langford, A. D. Hasler, Robert Hunt, Harold Schomer. Front row (L to R): Hugo Baum, Edward Schneberger, C. Juday, Sam X. Cross, Militzer, and William Spoor. Source: State Historical Society of Wisconsin.

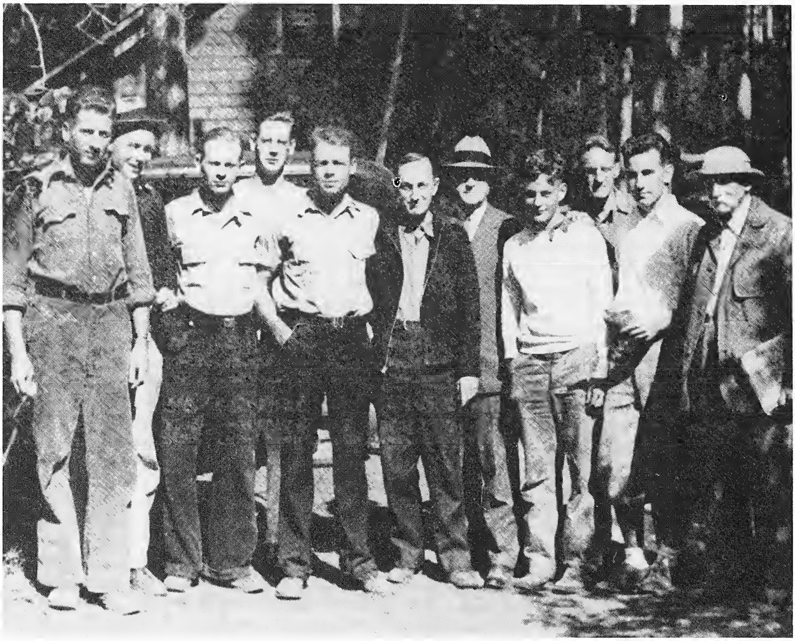

Fig. 12. The Trout Lake Crew in the summer of 1934. (L to R): David Frey, Martin Baum, John Schreiner, Don Kerst, Harold Schomer, C. Juday, E. B. Fred, Richard Juday, A. D. Hasler, Paul Pavcek, and E. A. Birge. Source: State Historical Society of Wisconsin.

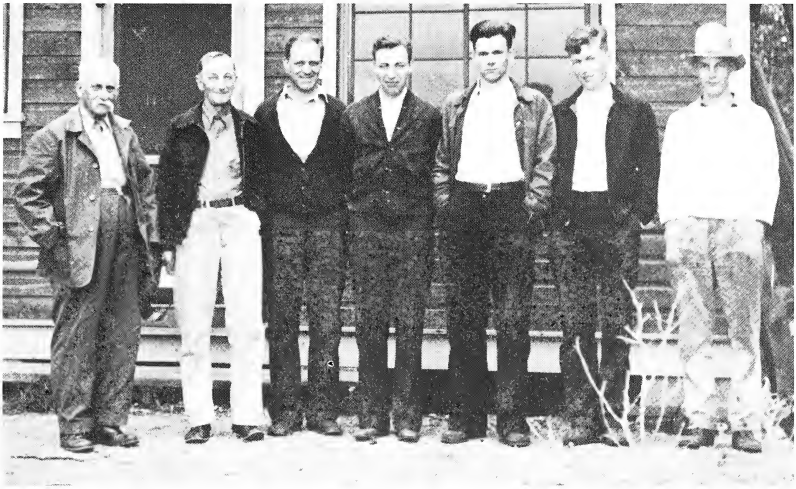

Fig. 13. The Trout Lake Crew in the summer of 1935. (L to R): E. A. Birge, C. Juday, Lester Whitney, Delmont Lohuis, John Curtis, Martin Baum, Richard Juday. Source: Robert Pennak.

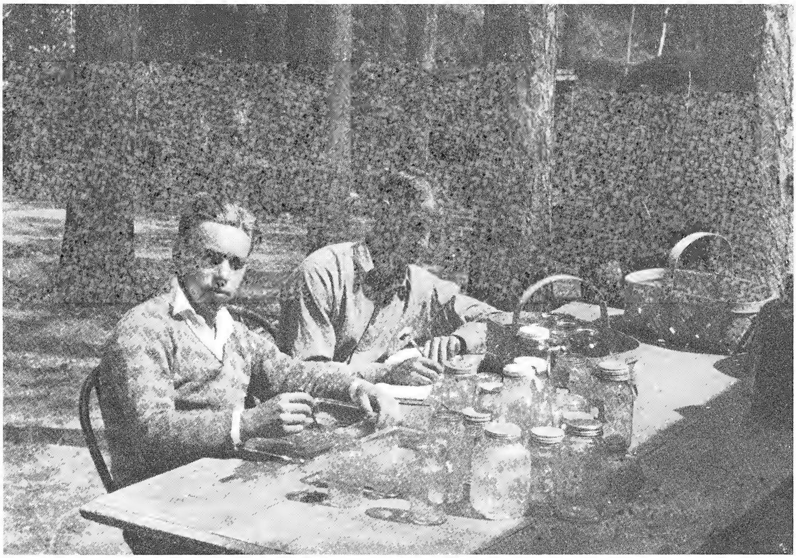

Fig. 14. Robert Pennak and Al Dimond counting benthic fauna, Trout Lake Station, 1937. Source: Robert Pennak.

Fig. 15. The Trout Lake Crew in the summer of 1938. Back row (L to R): Robert Pennak, Lester Whitney, Paul Conger, Herbert Stecker, Richard Juday, Gerald Prescott, L. R. Wilson, Willard Van Engel, and Nelson Rogers. Front row (L to R): Francis Davis, Donald Farner, Winston Manning, C. Juday, E. A. Birge, George Clarke, and Gillette. Source: State Historical Society of Wisconsin.

Fig. 16. Trout Lake Station about 1940. Source: Charles Kirkpatrick.

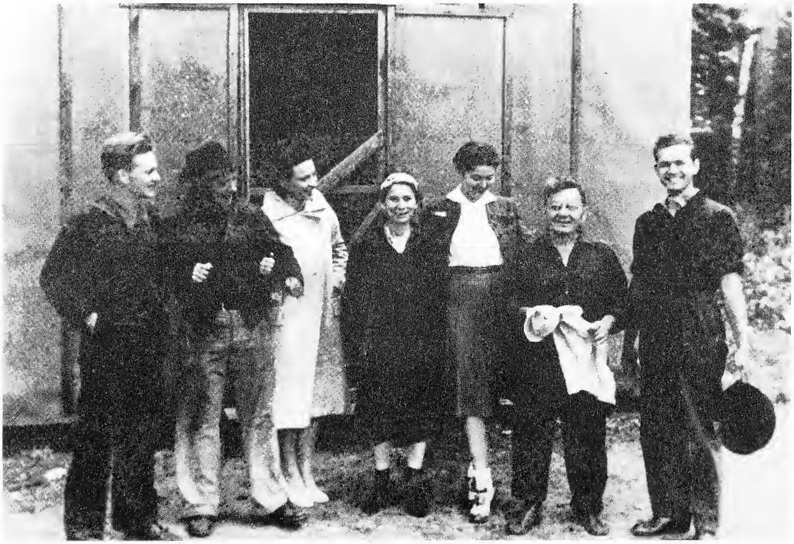

Fig. 17. Part of Trout Lake Crew in 1940. (L to R): Charles Moore, Vincent McKelvey, Genevieve McKelvey, unidentified, Gail Kirkpatrick, John Potzger, and Fred Granburg. Source: Charles Kirkpatrick.

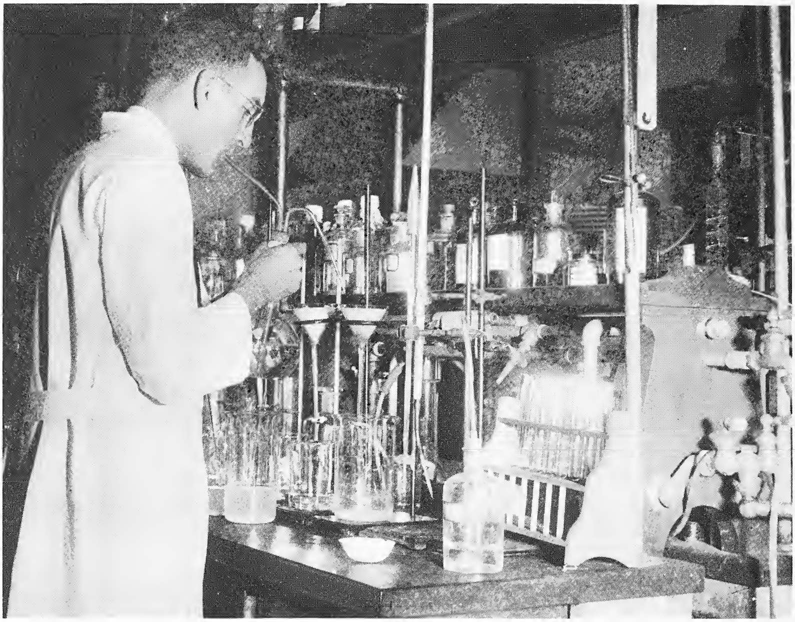

Fig. 18. Arthur D. Hasler at U.S. Fisheries Service Laboratory in Yorktown, Virginia, 1936. Source: Arthur Hasler.

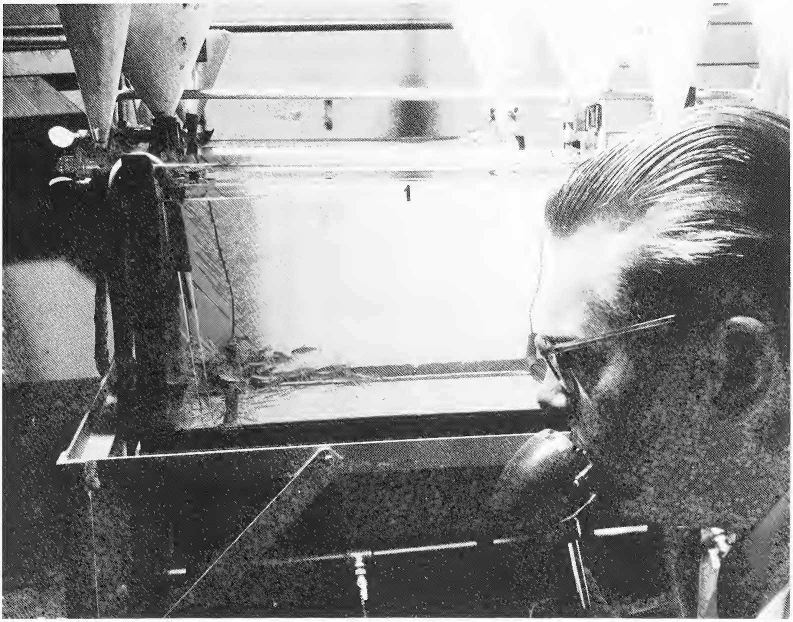

Fig. 19. Warren Wisby training bluntnosed minnows to identify the water from different Wisconsin rivers by the sense of smell, about 1951. Positive training is by food reward; negative, by mild electrical shock. This work on behavior by smell led to studies of olfactory imprinting in homing salmon. Source: Arthur Hasler.

Fig. 20. Fritz Hasler, A. D. Hasler's son, sprays fluidized $Ca(OH)_2$ hydrated lime or calcium hydroxide on Peter Lake to alkalize the water and precipitate the bog colloids that reduce water clarity, about 1952. The adjoining Paul Lake serves as the untreated reference lake. Peter and Paul Lakes are in the University of Notre Dame Environmental Research Center in Michigan. Source: Arthur Hasler.

Fig. 21. William R. Schmitz and A. D. Hasler at Saw Mill Pond on the Guido Rahr Property adjacent to the University of Notre Dame Environmental Research Center, about 1956. They are studying the possibility of using air bubbles to "turn over a lake," that is, disturb the stratification of the lake and thereby aerate it. The air tube goes the full length of the lake. Source: Arthur Hasler.

Fig. 22. A. D. Hasler and Wolfgang Braemer, a German ethologist from the Max Planck Institut, studying sun-compass orientation in fish, about 1957. Fish were placed in the center of the tank and trained to enter only the northerly compartments. The shade, peace, and quiet of a chamber were the rewards. Electric shock was given if incorrect direction was taken. Source: Arthur Hasler.

Fig. 23. William Helm and Wisconsin's first operational boom shocker, 1958. The shocker was built by Helm and was used for his walleye studies on Little John, Erickson, and Sparkling Lakes in northcentral Wisconsin. Source: William Helm.

Fig. 24. Physicist John W. Anderegg, Gene Likens, and A. D. Hasler on Cather Lake in northern Wisconsin about 1961. Anderegg is holding a scintillation counter used for the detection of isotopes in a study of the movement of radioactive nuclides from the bottom of a stratified lake. Source: Arthur Hasler.

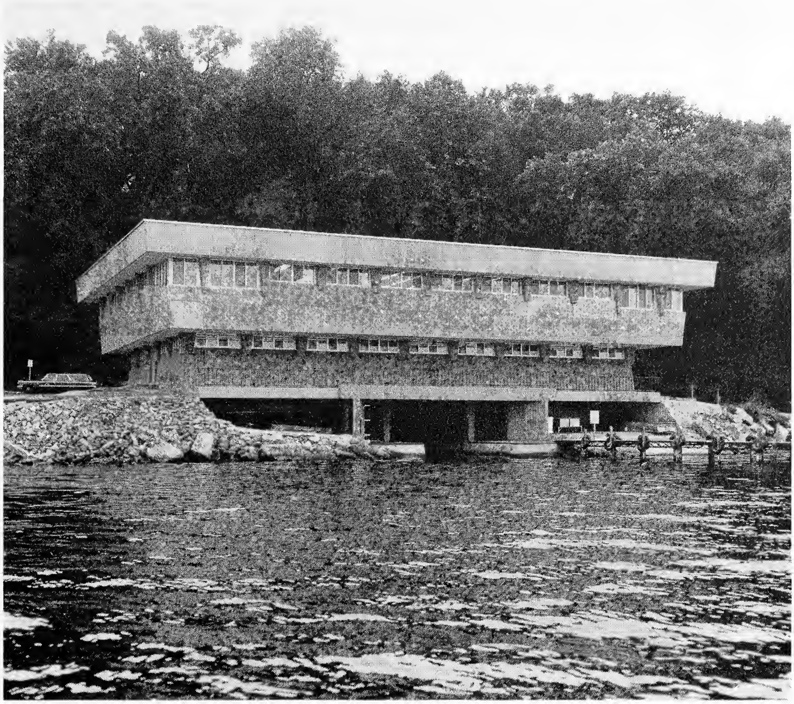

Fig. 25. The Limnology Laboratory on Lake Mendota shortly after it was built in 1963. The building was designed by architect William Kaeser. Source: Arthur Hasler.

Fig. 26. Limnology Laboratory Crew in 1964. Back row: Clyde Voigtlander, Allan Kingsbury, Don McNaught, Erich Schwartz, John Williamson, Tom Wright, Ed Gardella, Jim Bruins, Pete Wall, Paul Sager, Phil Doepke, Nick Lenz. Second row: Gary Hergenrader, Kenton Stewart, Jonce Sapkarev, Ken Maleug, Fran Henderson, Gerald Chipman, Andy Dizon, David White. Front row: Arthur Hasler, Mits Teraguchi, Arne Salli, Henry Eichhorn, Tom Wirth, Russell Dunst, Mike Parker. Source: Arthur Hasler.

Fig. 27. A. D. Hasler, Francis Henderson, and Gerald Chipman tracking fish that have been released with electronic transmitters in Lake Mendota, about 1965. Source: Arthur Hasler.

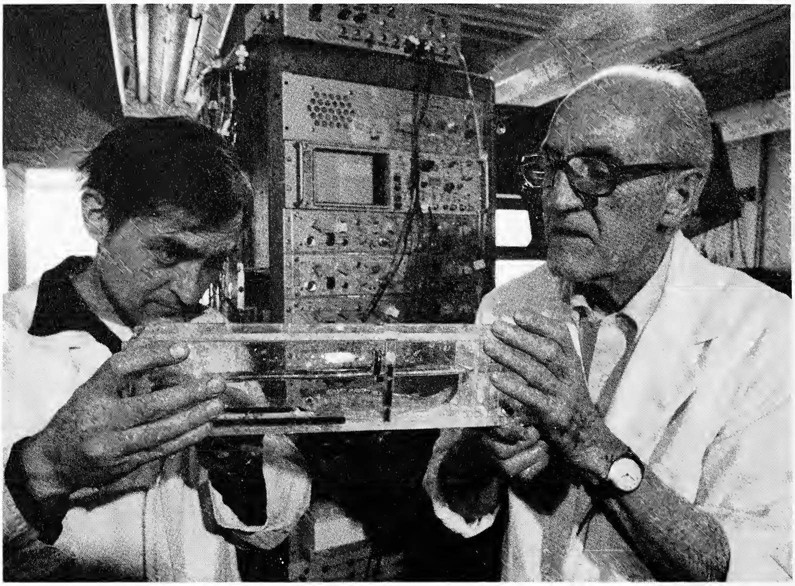

Fig. 28. Peter Hirsch and A. D. Hasler conditioning the hearts of fish to electric shock, about 1976. When one odor is presented the fish receives an electric shock; it receives no shock when a second odor is presented. After the fish is trained, it is possible to determine when it detects the odor because its heart stops beating. This technique is thought to have greater validity than direct electronic monitoring of the olfactory bulb. Source: Arthur Hasler.

Fig. 29. Participants in the 1983 "History of Limnology in Wisconsin" conference with the Trout Lake Laboratory in the background. First row: Arthur D. Hasler, Walt Haag (Center for Limnology facilities manager). Frank Egerton (UW Parkside science historian), Annamarie Beckel (CFL assistant researcher), Thomas Frost (CFL Associate Director for the Trout Lake Station), Robert Ragotzkie (former student of Hasler), Paula Barbian (CFL research specialist). Second row: John Magnuson (CFL Director), Robert Pennak (former student of Juday), Gail Kirkpatrick, L. R. Wilson (former associate of Birge and Juday), Edward Schneberger (former student of Juday), Gerald Prescott (former associate of Birge and Juday), Herbert Dutton (former associate of Juday). Third row: Jean Lang (University-Industry Research Program), Carl Bowser (UW Dept. Geology and Geophysics), David Frey (former student of Juday), Charles Kirkpatrick (former associate of Juday), William Helm (former student of Hasler), Fredrick Stare (former associate of Birge and Juday), Timothy Kratz (CFL associate scientist), Richard Juday (son of Chancey Juday). Not shown: William Schmitz (former student of Hasler), Helen Schneberger. Source: Don Chandler.

Fig. 30. "Old-timers" at the 1983 History Conference. Front row: Robert Pennak, L. R. Wilson, Arthur Hasler, Edward Schneberger, Charles Kirkpatrick, Gail Kirkpatrick, Fredrick Stare. Second row: Richard Juday, Gerald Prescott, David Frey, Herbert Dutton. Source: Don Chandler.

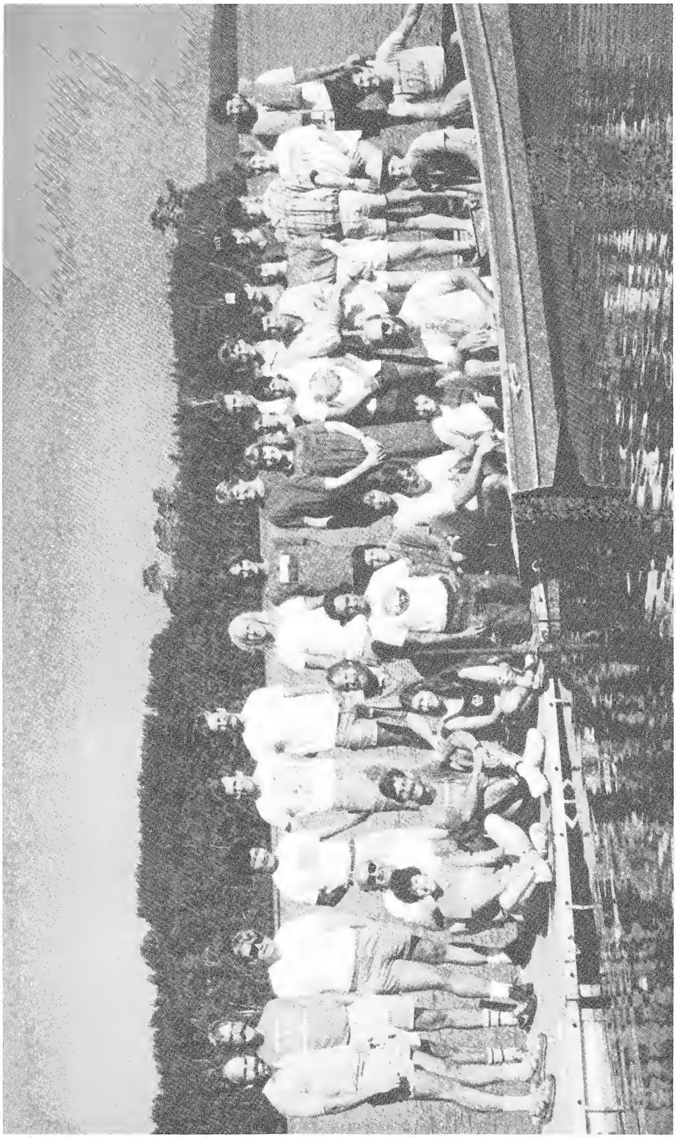

Fig. 31. The Trout Lake crew in the summer of 1987. Front Row: *Susan Knight, Walt Haag, Tim Kratz, Joan Elias, Tim Meinke, Dan Schneider, Louise Weber, Yan Zhao, Rick Hanson, Amy McMillan, Malcolm Butler, Doug Lieurance, Ned Grossnickle.* Back Row: *Tom Frost, Carl Watras, Ken Brown, Xi He, Steve Klosiewski, Christer Bronmark, John Morrice, Robert Walasek, Erik Schoff, Annamarie Beckel, Emily Greenberg, Michelle Marron, Dave Benkowski, Amy Finley, Mark Kershner, Dave Simon, Lauren Elmore, Ned Haight, Robert Wood, Pat Charlebois, Tim Simonson.*

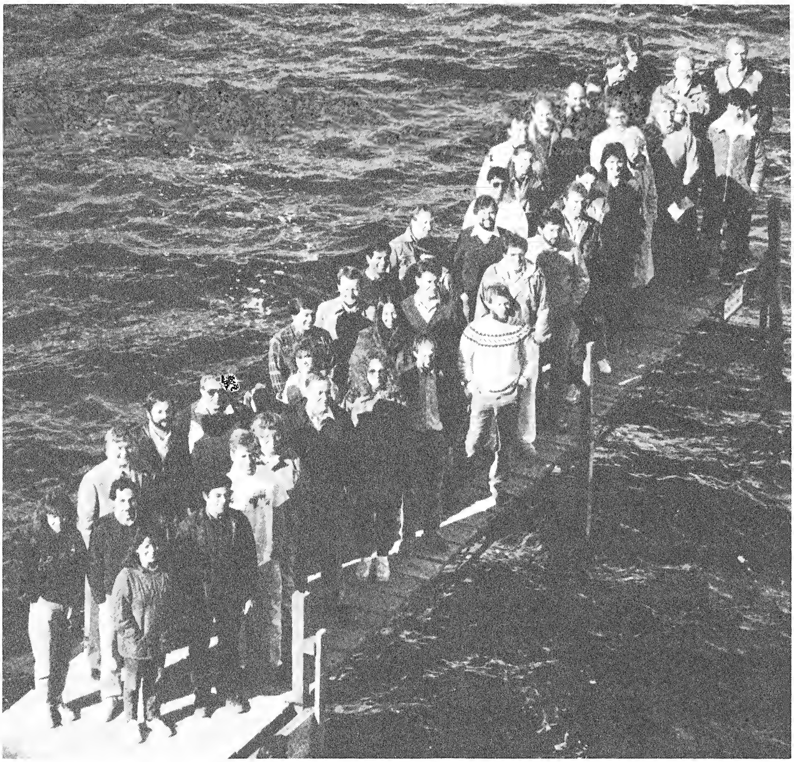

Fig. 32. Personnel at Lake Mendota Laboratory in the fall of 1987. Front Row: *Maria Gonzalez, Dan Schneider, Jim Yasko, Barbara Benson, Gerald Chipman, Joyce Tynan, Dennis Heisey, Redwood Nero, Dale Robertson, John Post, Dave Benkowski, Pat Sanford, Paula Barbian, Linda Holthaus, Rob Striegl, Jim Kitchell, Xi He, Don Stewart, Cliff Kraft.* Back Row: *Jo Temte, Mike Vanni, John Magnuson, Dave Egger, Glen Lee, Myriam Ibarra, Jennifer Twomey, Terry Schenck, Mary Smith, Barry Johnson, Mike Miller, Muhamed Alam, Connie Linehan (hidden), Greg Slater, Steve Carpenter, Charoen Nitithamyong, Cindy Lunte, Jay Nelson, Rusty Wright, Tom Frost, Mike Jech, David Hill, Paul Jacobson.*

5 The Wisconsin Limnology Community

Frank N. Egerton

The Wisconsin limnology community appears to have been foremost in America throughout this century. This chapter focuses upon the development and operation of this community during the periods in which it was run first by Edward Asahel Birge and Chancey Juday and then by Arthur Davis Hasler. Unlike the previous chapters, which dealt primarily with how the participants themselves viewed their own experiences in the Wisconsin limnological school, this chapter takes a more analytical and sociological approach to investigating the development of a scientific community.

Although historical studies published in the past two decades leave us much better informed than previously about the history of ecology (Egerton 1977, 1983–1985, McIntosh 1985), much of the history of ecology for the twentieth century has yet to be written. Writing it is a formidable task because of the diffuseness of the science and the sheer volume of contributions from ecologists. One needs a definite point of view. The one used here—the history of a scientific school—provides not only a point of view, but also yields some different conclusions than earlier historical accounts of the Wisconsin limnological community.

The three basic requirements for a cohesive scientific community are scientists, ideas, and resources—both financial and material. Any active group of scientists will possess all of these, but to transform a group into a scientific community, one or more of the scientists must provide a coherent research program that the group follows. To understand a particular scientific community, one must discover the important characteristics of its scientists, ideas, and resources. These basic attributes are so different in the Wisconsin limnological community under Birge and Juday and under Hasler that one could argue they were different even though the Hasler community grew out of the Birge and Juday tradition. The Birge-Juday period is already fairly well known from earlier historical accounts. The Hasler period is less well known. Fortunately, I am able to draw upon Hasler's memories as a resource. For these two reasons I devote more discussion to the Wisconsin school under his direction than under Birge and Juday's.

Ronald Tobey has already used effectively this approach of focusing on a scientific community to write the history of "the first coherent group of ecologists in the United States, the grassland ecologists of the Midwest" (1981: 5). However, it was not just grassland ecology that arose in America's Midwest but also terrestrial animal ecology and limnology. Price (1963) has argued that it is easier for new sciences to arise in young universities than in older ones, where the funds for science are already committed to established sciences. In the 1890s, when the ecological sciences arose, eastern universities were decades, if not centuries, older than midwestern ones. Not surprisingly, then, limnology arose in the Great Lakes states. The science was not stimulated by proximity to the Great Lakes, however. Investigations on large lakes require more elaborate and expensive equipment than those on smaller lakes, and when a science gets started, research budgets are usually limited (Beeton and Chandler 1963: 537). It was the numerous small lakes in the glaciated areas of these states that first challenged America's limnologists.

A historian of a limnological community in North America starts off in a better position than did Tobey when he began work on the history of American plant ecology, because American limnologists have already written a partly historical assessment of their science (Frey 1963a). The occasion for doing so was the meeting in Wisconsin of the 15th Congress of the International Association of Limnology held in 1962. The initiative for writing *Limnology in North America* came from David G. Frey and Arthur D. Hasler, both former graduate students at Wisconsin. Frey wrote the first chapter, "Wisconsin: The Birge-Juday Era" (1963b), and Hasler the second, "Wisconsin, 1940–1961" (1963a). No other state is accorded two chapters and most of the chapters encompass several states. Because *Limnology in North America* was published by the University of Wisconsin Press and its publication was arranged by two limnologists who received doctorates from that state's university, one may wonder if the history of limnology in Wisconsin received preferential emphasis. A Wisconsin historian is not the best judge of the matter, but I can point out that the Congress was held in this state in recognition of the achievements of the Wisconsin limnological school.

Scientists in Michigan, Illinois, Indiana, and Ohio also produced important early contributions to limnology. Michigan and Illinois are given chapters in the book, but Indiana and Ohio are lumped together into a regional chapter with Tennessee, Kentucky, and West Virginia (Gerking 1963). Judging by the book's space allocations, only Illinois and Michigan rate serious consideration as early rivals for leadership with Wisconsin. If Illinois is compared with either Wisconsin or Michigan in this respect, it is rather like comparing prairie ecology at the Universities of Nebraska and Chicago, the one being in the midst of the prairie and the other on its edge. In Illinois rivers are much more prominent than lakes, and, correspondingly, limnology was oriented toward rivers (Gunning 1963). On the other hand, both Michigan and Wisconsin have numerous lakes formed by glaciers. Michigan's limnological work seems to be the strongest rival to Wisconsin's (Chandler 1963, Robertson 1976). The early differences in limnology at Michigan and Wisconsin are not easily summarized, but in the long run Wisconsin distinguished itself under Birge and Juday by emphasis on energy budgets of lakes and under Hasler by emphasis on experimentation.

The Birge-Juday Period

Tobey (1981) is undoubtedly correct in seeing the relative success of different scientific communities as due to a combination of intellectual, social, and other factors. When one evaluates these factors in plant ecology, Frederic E. Clements, the founder of the Nebraska school, does not seem to have had a suitable personality for founding a scientific community. He lacked an outgoing personality; he had no charisma. He was absorbed in his research, and after a decade of teaching he exchanged his academic career for one as a full-time research scientist at the Carnegie Institution of Washington. Clements was, however, probably indispensable as founder of the Nebraska community of prairie ecology, and his publications dominated the outlook there for four decades. Yet, it was his student and collaborator, John Weaver, who did most of the training of the other students, without whom there might have been a Nebraska collaboration, but no cohesive community.

With regard to the characteristics of its founder, the situation in limnology at Madison, Wisconsin, was not very different from that in plant ecology at Lincoln, Nebraska. The founder of the Wisconsin school of limnology was Edward A. Birge, whose career indicates that he also was more absorbed in research and administration than in teaching. His personality was as stiff as Clements'. Although he never left the university, when opportunity came, he did leave the classroom (in 1911) for various administrative posts, including, finally, the presidency of the university (Sellery 1956). He apparently also lost interest in training biologists. Lowell E. Noland, while a graduate student in zoology, worked one summer as Birge's research assistant at Trout Lake, and in the fall back in Madison, Birge would walk by him with no sign of recognition (pers. comm.).

Birge began his career as an invertebrate zoologist. He had gone to Williams College in 1869 to prepare for medical school, but stayed on after receiving his B.A. degree to earn a M.A. degree in science. He went to Harvard for his doctoral degree, where he was Louis Agassiz's last student, though Agassiz died shortly after Birge arrived. Although one might argue that Agassiz had established a comparative zoology community at Harvard, virtually all of his students defected from Agassiz's Cuverian paradigm to some form of evolutionary biology. Moreover, with Agassiz past his prime, whatever community of zoology he had once held together had all but disappeared before Birge arrived (Dexter 1965, 1974, 1979). Birge certainly learned some zoology from him, but he must have learned little or nothing about running a scientific community.

Birge's studies on invertebrates in Lake Mendota led him as easily into limnology as had similar studies on Lake Geneva led François A. Forel into this science several decades earlier (Egerton 1962, 1978). Although Forel spent practically his entire career teaching anatomy and physiology to premedical students at the Académie de Genève in Lausanne and never trained limnologists, he is the true founder of this science. His great study on all aspects of science concerning Lake Geneva (1892–1904) may still be the most exhaustive monograph on any lake in the world. He realized, however, that beginning students could not be expected to read his three large volumes; he therefore published the first textbook on limnology (1901).

Tobey attributes the distinctive character of prairie ecology in Nebraska in part to Clements' attempt to adapt the methods that C. G. Oscar Drude used in the forests of Germany to the prairies of America. Birge faced a less dramatic challenge in his transfer of Forel's methods to Wisconsin lakes, although in his long scientific career Birge would have plenty of opportunities to develop new methods and equipment.

Just as Clements' publications dominated American plant ecology from the early 1900s until World War II, so Birge's dominated American limnology during the same period. And, as Clements had Weaver to train disciples, so Birge had Chancey Juday. Of course, there were differences as well as similarities between the situations at Nebraska and Wisconsin. Juday was not one of Birge's students. He had studied limnology at Indiana University under Carl Eigenmann and had then come to Madison in 1900, with only a master's degree, as Birge's assistant and collaborator. In 1908 he visited European universities and field stations engaged in hydrobiological research (Juday 1910), which was for him "a great stimulus, an insight into the newer approaches in European limnology, and contact with the leading men in the field" (Noland 1950: 96).

Both Birge and Juday, in the development of their limnological interests, made the same kind of progression that Forel had, from a strong interest in the invertebrate life in lakes, to the quest for the factors controlling those life forms, particularly the physical and chemical attributes of lakes (Mortimer 1956, Frey 1963b). The shift in emphasis was gradual and never led to abandonment of their earlier interests. The turning point seems to have been Birge's masterful presidential address to the American Microscopical Society in July, 1903, on "The Thermocline and Its Biological Significance" (Birge 1904). Although he did not discover the thermocline, by measuring the temperature of lake waters at different seasons of the year, Birge made the first thorough study on the thermocline and the mixing of waters in spring and fall in lakes in temperate climates. He also explained the implications of temperature stratification for the life of lakes. He, Juday, and their collaborators also studied light penetration, dissolved minerals, and hydrogen ion concentration in the lakes of Wisconsin.

Unlike Clements, Birge did not develop a comprehensive theory to guide his research and that of his co-workers and thereby provide intellectual cohesion for the Wisconsin community. One reason the early differences between the Wisconsin and Michigan schools of limnology are not very obvious is that in America limnology did not develop the theoretical polarity that Tobey claims distinguished the Nebraska and Chicago communities of prairie ecology. Nevertheless, Birge and Juday had a definite research agenda. They, with their research associates and students, took an inventory of the environmental factors that prevailed in the Wisconsin lakes, and they monitored various environmental factors at different lakes for various periods. Their late emphasis upon the energy budgets of lakes constitutes, if not a theory, at least a theoretical perspective.

Birge never had doctoral students; he did supervise the thesis research of two or three dozen candidates for the bachelor's degree and also those of a few candidates for the master's degree. Juday began lecturing in limnology in 1909. However, he might never have advised graduate students had not his position with the Wisconsin Geological and Natural History Survey been eliminated entirely during the Depression year of 1931. Subsequently, Birge was able to have him appointed to a professorship in zoology at the university. The research on which Juday collaborated with Birge was more than equivalent to writing a doctoral dissertation, and in 1933 Indiana University bestowed upon him an honorary doctoral degree.

Juday was to supervise the doctoral research of 13 graduate students (listed in the appendix). One of them, Robert W. Pennak, later dedicated his *Fresh-Water Invertebrates of the United States* (2nd ed., 1978) "To the memory of C. Juday." It may seem surprising that a leading community of limnology produced only 13 doctorates in its first four decades. However, this is at the same rate doctorates in prairie ecology were being graduated from the University of Nebraska during the same period (Tobey 1981: 120–121). Had either university produced two or three times as many, some of them would have had difficulty finding suitable jobs. The Depression was a bad time to be a graduate student or to look for employment.

An ecology community that produces only 13 doctorates in four decades may be respectable, but is it a leading community? The minimal requirement of a leading scientific community is probably that it produces both outstanding students and outstanding scientific contributions. The quantity of both need not be great, but surely it is unusual for a leading scientific community not to produce a high number of either students or publications. The Wisconsin limnological group in the Birge-Juday period was very productive in publications. Since its productivity in students was not high, how did it manage to be so productive in research? High productivity is usually a result of having many students engaged in publishable research. Birge and Juday's great industry and commitment to research were important, but not sufficient to account for all the papers that were published. If students did not do a large portion of the research as thesis projects, who did? Some of it was done by hired student assistants, such as Noland who worked for Birge that summer at Trout Lake. However, a large portion of it was done by other scientists, mostly on the faculty of the University of Wisconsin, but some hired briefly by the Wisconsin Geological and Natural History Survey, and later by the Works Progress Administration.

The Wisconsin limnological school under Birge and Juday was probably very atypical of successful scientific groups. Until 1925 the community was small and not very cohesive. There was a Birge-Juday research partnership and occasional graduate students whose limnology-related dissertations were supported by the Wisconsin Geological and Natural History Survey. Examples of this type of work include research done by Smith, Rickett, and Schuette.

The study of lake algae began in the 1910s and 1920s when Gilbert Morgan Smith (b. 1885) compiled lists of algal species found in Wisconsin lakes for the Wisconsin Geological and Natural History Survey. Smith's interests were not limited to taxonomy, however, as indicated in his study of "The Vertical Distribution of Volvox in the Plankton of Lake Monona" (1918). He was from Beloit and received his B.S. degree from Beloit College in 1907. He took his Ph.D. in botany from the University of Wisconsin in 1913, and was a member of the botany faculty until he left for Stanford University in 1925.

Harold W. Rickett (b. 1896) received his bachelor's, master's and doctor's degrees from the University of Wisconsin and stayed on two years as an instructor before leaving for the University of Missouri in 1924. While at Wisconsin, he published quantitative studies on the larger aquatic plants in Lake Mendota and Green Lake (1920, 1921, 1924).

Henry A. Schuette (1885–1978) was from Green Bay, educated in chemistry at the University of Wisconsin, and was a member of the university's chemistry faculty for his entire career. He wrote a doctoral dissertation on the biochemistry of plankton in Lake Mendota (Ph.D. 1916, dissertation published in 1918) and retained a research involvement in the biochemistry of aquatic plants for another decade (Frey 1963b: 30, 52) before turning to his main researches on the biochemistry of human foods (Ihde 1978).

The addition of such studies to the work of Birge and Juday added to the intellectual foundation for a scientific community. However, more was needed before one could say that a community existed.

Most university professors give up research in their discipline when they become administrators. Those who do not generally conduct research at a lesiurely pace. The fact that Birge could continue his research even while president of the university (1918–1925) is probably owing to his long years of working with Juday. During these years Birge could have merely discussed what needed to be done with Juday and depended upon the latter to carry out the actual work, with Birge stepping in again to assist in evaluating the results and writing the papers for publication. When Birge retired from the presidency on September 1, 1925, six days before his 74th birthday, he and Juday had won a distinguished reputation for the scope and quality of their work. If Birge had rested on his laurels and played bridge and shuffle board for the rest of his life an outstanding limnological community at the University of Wisconsin might never have come into being.

Once free of other responsibilities, however, Birge's research ambitions were far greater than he and Juday alone could ever accomplish. The conventional way to satisfy such ambitions is for a professor to attract graduate students to share in the research. This avenue was not open to a retired professor, however, and apparently he had not yet thought of having Juday made a professor. The high quantity and quality of scientific papers that the Wisconsin limnological school ultimately published required the participation of many experienced scientists. Such an aggregation could seldom have been assembled anywhere before World War II because of financial constraints. A university professor ordinarily could not build a very large "empire" on campus because he could not provide the financial and social incentives to lure colleagues away from the priorities established within their own disciplines.

What incentives could Birge offer his colleagues that were strong enough to enable him to build a much larger "empire" than was commonly possible? As an eminent retired scientist/administrator, he continued to have considerable influence within the university, and collaboration with him might enhance one's career. Furthermore, he could provide research funds, equipment, and facilities. Although the Carnegie Institution of Washington began supporting ecological research early in this century (Colin 1980, McIntosh 1983), it supported the work of only a few scientists. During those years the federal government mainly supported research done by its own scientists (Dupree 1957). The research of science professors at state universities was usually supported with state funds, which were seldom ample. Although Birge was on record as opposed to any university policy favoring one department to the detriment of another (Sellery 1956: 19), his impartiality must not have applied to competition for research funds. His clout as an administrator apparently was used to channel a disproportionate amount of university funds into limnological research.

Even so, these university funds were not enough to satisfy the needs of his research program. Therefore, he came to dominate two other state institutions that could provide additional funds: the Wisconsin Academy of Sciences, Arts and Letters and the Wisconsin Geological and Natural History Survey. The Academy is a private organization, the Survey, a state organization. Birge was director of the latter from its establishment in 1898 until funding for the Natural History section was discontinued in 1931. He thus controlled both the research and publication funds of the Survey, and he was the heaviest user of the publication funds of the Academy.

In 1925, after retiring, Birge established a limnological research station in northern Wisconsin at Trout Lake, where he and Juday conducted much of their own summer's research, and where they brought both graduate students (often in non-biological sciences) and visiting scientists to conduct research. Some of his colleagues in Madison believed that Birge decided to establish the station in northern Wisconsin so that he could study lakes and their life away from human pollution. The pleasant summer climate at Trout Lake must have been encouraging. More importantly, Birge and Juday had already studied intensively several lakes in southern Wisconsin. The major attraction of northern Wisconsin was the great variety of pollution-free lakes. By conducting extensive surveys there they were hoping to find general principles that would apply to all lakes. For some of these researches they tapped still another new source of funding, the Wisconsin Conservation Department.

The University of Wisconsin was not a pioneer in establishing a limnological research station. In fact, it was rather much slower than neighboring states in doing so. The university's Madison campus is located on one lake and near a string of others. Because these lakes were fully utilized by limnologists from the earliest days of Birge, it would have been difficult to make a compelling case to the university administration for building student facilities at Trout Lake. Even now, the summer courses in limnology are taught in Madison. Thus, the Trout Lake station has always been exclusively for research. At times, this meant that the university administration felt less concerned for its fate than it might have if the station had been a teaching facility. On the other hand, the facilities there probably accommodated more research scientists than would have been convenient if its existence had ever been justified on the basis of a teaching mission.

Frey (1963b: 29) surveyed the productivity of this school from 1924 to 1944 and found that

> during this interval more than 260 papers were published by the Wisconsin group and their associates. The peak came in the late '30's and early '40's, with as many as 34 papers listed for a single year (Juday and Hasler, 1946). During this period the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* were dominated by the enormous and varied limnological output of this group of limnologists, sometimes to the virtual exclusion of other studies.

This domination was achieved at the cost of some colleagiality. The university's Professor of Chemistry and History of Science, Aaron J. Ihde, recalls that (pers. comm.)

> the limnologists created a bad storm in the Academy because they virtually monopolized the *Transactions,* to the exclusion of the papers of members in other areas. I remember caustic remarks at the time and the dissent probably forced the limnologists to eventually publish elsewhere. Birge was, of course, still active and no one in the Academy was anxious to cross swords with him. However, 34 papers in one volume was too much for even the timid academicians.

The involvements of the faculty members ranged from one-time to long-time. Most of them established reputations independently of the limnological community, but a few were known primarily for their work with the group. Some of these collaborations are discussed briefly by Frey and are also indicated by the authorships and acknowledgements of the papers listed in Frey's "Wisconsin: The Birge-Juday Era" (1963b: 44–54). It will suffice here to discuss briefly some of the more important collaborators in order to indicate the nature of their involvement with the limnological community.

The Botany Department evidently regretted losing Rickett, whom it had trained in the study of aquatic vascular plants, because in 1925 it hired another with this specialization: Norman C. Fassett (1900–1954), from Massachusetts; his degrees were all from Harvard. Fassett's *Manual of Aquatic Plants* (1940; 2nd ed., 1957) became the standard work on the subject for North America. Fassett had "a forceful and stimulating personality," and he devoted much time and care to building up the university's herbarium (Bean et al. 1954). Another botanical collaborator who enjoyed a national reputation was John T. Curtis (1913–1961). From Waukesha, he received his bachelor's degree from Carroll College in 1934 and his Ph.D. from the University of Wisconsin in 1937. His interests were broad, and when he worked with Juday in 1935 Curtis was a plant physiologist. However, during and after World War II, Curtis' interests shifted to plant ecology. His *Vegetation of Wisconsin* (1959) remains a classic, both for its accurate picture of Wisconsin's vegetation and as a model for other studies (Cottam *et al.* 1961, Stearns 1961).

In bacteriology, the limnologists were able to attract the collaboration of the remarkable Edwin B. Fred (1887–1981) long enough to get four papers published in 1924–1925 concerning the ecology of lake bacteria, but Fred was too busy with his own scientific and administrative goals to be absorbed for long into someone else's group (D. Johnson 1974). However, as Dean of the Graduate School (1935–1943) Fred was in a powerful position to assist administratively with Birge and Juday's research. Furthermore, Fred's student, Elizabeth McCoy (1903–1978), who became his colleague and sometimes his collaborator, occasionally became actively involved with the limnological school from the 1930s onward. She was a native of Madison and owned a farm on the banks of Lake Monona. Her concern for preserving Wisconsin's lakes and streams motivated her to continue research on lake bacteria even after her retirement. Her value as a collaborator is indicated in this judgement from her colleagues: "It is doubtful that anyone can match Elizabeth McCoy's breadth and depth of knowledge about microorganisms and their activities" (Bennett *et al.* 1978).

The limnologists had a number of important chemistry collaborators. George I. Kemmerer (1879–1928), from Janesville, was motivated to collaborate, in part at least, by his lifelong interest in "the application of scientific methods in the study of problems related to fish and game conservation" (Mathews *et al.* 1928, Ihde 1975). William H. Peterson (1880–1960), a professor of biochemistry, came to the University of Wisconsin after receiving his master's degree from Columbia University in 1909. He then taught chemistry to home economics students while earning his Ph.D. from the university in agricultural chemistry. He is best known for his long-time collaboration in research with E. B. Fred. He was also the dissertation advisor to more than fifty doctoral students. He published, either alone or in collaboration, more than 300 scientific papers—mostly on the chemistry of microorganisms (Baldwin *et al.* 1960).

One of Peterson's students was Bernhard P. Domogalla (1894–1970), from Milwaukee, who collaborated with Peterson, Fred, and Juday in the mid 1920s in studies on the nitrogen content of lakes around Madison. As a student Domogalla assisted Birge in taking lake temperatures. The story of Birge's notorious instructions to him one winter day is told elsewhere in this volume. Domogalla served as the biochemist for Madison (1924–1946). Because Lakes Mendota and Monona, which are adjacent to the city, began experiencing repulsive algal blooms in summer from eutrophication caused by sewage, Domogalla experimented for eleven years with the application of copper sulfate to the lakes. Copper sulfate was applied by the freight car load in concentrations high enough to kill algae, but presumably low enough to spare fish (Domogalla 1935, 1941, Brock 1985). His researches eventually led to the development of the commercially significant algicide, Cutrine. He occasionally employed university faculty and students for city water research, but by 1943 he was unable to obtain research funds for all his projects. Domogalla therefore employed a familiar Birge tactic and filed excess salary claims for his regular employees and used those funds to hire part-time research personnel. By 1946, when this practice was discovered, the misappropriated funds totaled $1220. He was forced to resign and to donate $3000 worth of his personal equipment to the city in restitution (*The Capital Times,* 18 Dec. 46). He then returned to Milwaukee and opened a biochemical consulting firm (Scott 1970), and was soon advising governments in North and South America on controlling water pollution (*Badger Chemist* no. 5, 1957: 8).

Villiers Willson ("Mel") Meloche (1895–1981) was an active collaborator with Birge and Juday in the 1930s. Their last joint paper appeared in 1941. Meloche was born in Port Huron, Michigan, but in 1905 his parents decided to move to Madison to enable their four children to take advantage of its educational opportunities. All four graduated from the University of Wisconsin, with Mel Meloche receiving three degrees and then joining the chemistry faculty. His involvements with Birge and Juday were similar to those of Kemmerer in the 1920s. Meloche enjoyed working at Trout Lake so much he made his summer home there, and he often had his graduate students come up during the summer and assist in his researches. He supervised the dissertations of 44 doctoral students in chemistry (Ihde 1981).

The geologist who actively collaborated with Birge and Juday was William Henry Twenhofel (1875–1957), a Kentuckian who had received his education at Yale, and who was a member of the Wisconsin faculty from 1916 until his retirement in 1945. He was widely known for his textbooks on sedimentation, and he and his students published a number of studies on the sediments in Wisconsin lakes in the 1930s and 1940s (Bryan *et al.* 1957).

Birge and Juday's main collaborator in physics was Lester Vincent Whitney (1902–1964), who was from Chicago but received his three physics degrees from the University of Wisconsin. He began working with Birge and Juday early in the 1930s and continued to do so after joining the faculty of Southwest Missouri State College in 1937. He studied the transmission of solar heat and light through the waters of Wisconsin lakes. His studies were supplemented by the physics dissertation of Harry Raymond James (b. 1890, Ph.D. 1934; see James and Birge 1938).

Zoologists are absent from the list of collaborators because that was Birge and Juday's area of expertise. Nevertheless, members of the zoology faculty also occasionally were included in limnological projects. For example, Frey's bibliography includes four papers written by Lowell E. Noland (1896–1972), an invertebrate zoologist on the faculty (Burns *et al.* 1972). A potentially valuable member of the Wisconsin limnological school was ecologist Arthur S. Pearse (1877–1956), who taught zoology at the University of Wisconsin from 1911 to 1927 and published eight papers on fish ecology cited by Frey. Although he enjoyed living in Madison, he left in 1927 because he felt that he had been assigned unfairly heavy teaching responsibilities (Pearse 1952: 32–34).

Some of the scientists from other states who worked for one or more summers at Trout Lake published studies that advanced the knowledge of Wisconsin limnology. For example, John E. Potzger (1886–1955), a professor of botany at Butler University, contributed five papers from 1942 to 1944 on the vascular plants along the shores of northern Wisconsin lakes (Frey 1963b: 51, Anon. 1956). Another example is Gerald W. Prescott (b. 1899), who would become well known for his research on North and South American algae. Prescott came to the Trout Lake Station from Albion College and later Michigan State University to study the taxonomy and distribution of algae in relation to the chemical characteristics of the lakes. Leonard R. Wilson (b. 1906), who had been one of Norman Fassett's Ph.D. students, returned to the station from Coe College in Iowa to investigate the distribution and quantity of aquatic plants in northern lakes.

G. Evelyn Hutchinson, who stayed too briefly to make such a contribution, has nevertheless published his recollection of his experience.

> Professor E. A. Birge and Professor Chancey Juday were kind enough to let me spend a week at the Trout Lake Laboratory in Vilas County, in northeastern Wisconsin. I had learned a fabulous amount about limnological technique but had come away with two feelings of dissatisfaction. One was that it would be nice to know how to put all their mass of data into some sort of informative scheme of general significance; the other was that it would be nice to have either tea or coffee, without seeming decadent and abnormal, for breakfast. I now suspect a connection.

The last thought occurred to Hutchinson when reflecting upon Juday's having advised the editor of *Ecology* not to publish Raymond Lindeman's paper on the trophic-dynamic concept because it was based upon insufficient data (Hutchinson 1979: 248; see also Cook 1977).

An important test of leadership for a scientific school is the recognition that its leaders receive from their peers. For Birge and Juday, that recognition is summarized by Frey (1963b: 6):

> Both men were active in national affairs, serving variously as president of the American Microscopical Society, American Fisheries Society, Ecological Society of America, and the Wisconsin Academy of Sciences, Arts, and Letters. Moreover, Juday was one of the persons instrumental in bringing about the birth of the Limnological Society of America, and he was elected president for its first two years. Juday was awarded the Leidy Medal by the Academy of Natural Sciences of Philadelphia in 1943, and Birge and Juday together were awarded the Einar Naumann Medal by the International Association of Limnology in 1950 in recognition of their important and numerous contributions to the field.

The Limnological Society of America was established in 1936; in 1948 it became the American Society of Limnology and Oceanography (Lauff 1963).

Birge retired from teaching in 1911, from the university presidency in 1925, and from his scientific research in 1941; he died in 1950 at age 98. Juday retired from teaching in 1937 and from the directorship of the Trout Lake Limnological Laboratory in 1942; he died in 1944 at age 73. Juday had had to work as long as he could because Birge had never arranged for him to receive any retirement pay from the Geological and Natural History Survey, though he may have received a little from the university. Mrs. Juday, after her husband's death, expressed her displeasure at Birge's neglect by not consulting him on the disposal of Juday's library. She sent his books to the Academy of Natural Sciences of Philadelphia.

The Hasler Period

Arthur Davis Hasler was one of those 13 students who obtained a doctorate under Juday. The continuity of the Wisconsin limnological community from Birge and Juday to Hasler would appear to be, therefore, a routine matter. In reality, it was far from routine, and limnology might well have been a casualty rather than a beneficiary of the transition if the university had hired a less determined and industrious limnologist than Professor Hasler proved to be. Birge and Juday both faded from the university scene just as the country was becoming distracted by World War II, and the post-war years were a period of such comprehensive readjustment that many traditions were discarded in favor of new approaches and new directions. Hasler was shrewd enough to wed the university's old commitment to limnology to new methods, and thereby emerge from the transition period with a stronger program than existed before he took over. To understand how and why this happened we need to examine his early life, education, and professional experience down to the time when he deliberately established his new methods for the Wisconsin limnological school.

He was born a Mormon at Lehi, Utah, on January 5, 1908. No one who knows him doubts his own strong conviction that his pioneering Mormon background provided him with ethical and intellectual values that contributed substantially to his successful career. His boyhood interests were in fishing, raising livestock, camping, nature study, and the Boy Scouts. These interests did not lead him inevitably into limnology, however. While an undergraduate at Brigham Young University he seriously considered following his father's example in becoming a physician and was only deflected from that by the financial constraints of the Depression and an ill father. While considering a medical career, however, he developed a permanent interest in physiology. His major in zoology encompassed both this new subject and also many of his boyhood interests. His broad interests were to be strong assets later when he directed the Wisconsin limnological school.

Having decided that it was financially more expedient to go to graduate school than medical school (in the former he could earn expense money as he studied), Hasler became a graduate student at Madison in 1932. Acting on the advice of A. S. Pearse and Juday, he minored in medical physiology and physiological chemistry. His major was zoology, with emphasis on limnology and the physiology of crustacea.

At the time, there was considerable interest in the food of plankton, especially in whether or not some of these organisms can use dissolved organic matter. Birge and Juday were themselves investigating aspects of the subject (1922, 1934). Juday suggested, therefore, that Hasler undertake his dissertation research on the physiology of digestion in plankton crustacea. Hasler agreed. Despite Birge and Juday's experience on related topics, Hasler performed his research under the supervision of Professor H. C. Bradley, in the Department of Physiological Chemistry. As an undergraduate, Hasler had learned in Professor Wayne Hale's chemistry class of the importance of duplicating experimental findings. Now, under Professor Bradley, it was a routine matter that "the experiments were duplicated and run with controls" (Hasler 1935: 212); routine, that is, in physiology and in physiological chemistry, and routine at certain biological laboratories at Woods Hole, where Hasler spent the summer of 1935 testing the results he had obtained from the fresh-water cladoceran, Daphnia, upon the marine copepod, Calanus (Hasler 1937). Experimental controls and duplication were not routine, however, in the Birge-Juday school.

By 1935, Hasler had had experience with controlled laboratory experiments and uncontrolled field experiments when he assisted Juday with the Weber Lake studies. While at Woods Hole, Paul Galtsoff of the U.S. Fish and Wildlife Service employed him to conduct research on the effects of sulfate pulp mill wastes on oysters in the lower stretches of the York River in Virginia. It was presumed that the wastes adversely affected the oysters, but proof of the significance of this pollution was needed before action could be taken. Hasler transferred sick oysters from the polluted York River to the nearby unpolluted Piankatank River (near where these rivers enter Chesapeake Bay) and healthy oysters from the Piankatank to the York. Undisturbed oysters in both locations served as controls. He found that sick oysters recovered when moved to the Piankatank and healthy oysters became sick when moved to the York (Galtsoff *et al.* 1947). This project constituted a large-scale controlled experiment in the field.

In 1937, at Prof. Michael F. Guyer's invitation, Hasler returned to the University of Wisconsin as an instructor. Neither Birge nor Juday offered Hasler any help in establishing his own limnological research after he returned. However, Guyer assigned to him a small two room laboratory on Lake Mendota. That was as far as the red carpet extended. Juday was still in charge of the Trout Lake station, and he did not invite Hasler to use it. Hasler was promoted to assistant professor in 1941, associate professor with tenure in 1945, and full professor in 1948. Yet, he did not feel free to use the Trout Lake station until 1950. There had been such strong faculty resentment toward Birge and Juday for administering the Trout Lake Station exclusively for limnology that a reaction set in with their departure, and the station was administered by scientists from other disciplines until 1962.

Clements had his Weaver and Birge his Juday, but Hasler had to establish and maintain his scientific community without a lieutenant. Not that he did not recognize the desirability of having one, and several times he attempted to obtain one. He agreed with the Department of Zoology's decision to hire his student, John C. Neess (Ph.D. 1949), believing that he would assume such a role. Neess, however, preferred to work alone. Neess also declined to seek outside funding to support research, which limited the scope of his and his students' research. When he obtained tenure, Hasler's chances of obtaining a lieutenant decreased. Nevertheless, Neess was available to help Hasler's students, and he was of substantial assistance to some of them, particularly with statistical and sampling problems.

Hasler thought he had finally gained a lieutenant in another of his former students, H. Francis Henderson (Ph.D. 1963), but Henderson was unable to obtain tenure (although he remains a productive fishery biologist, now with the U.N.'s Food and Agriculture Organization in Rome). With Henderson's departure, and at Hasler's recommendation, the Zoology Department in 1968 hired John J. Magnuson and appointed him Director of the Trout Lake Station. He was both a productive scientist and a "team player." Before Magnuson arrived, however, Hasler had already demonstrated his ability to maintain and direct a first-rate limnology community. How had he done so for so long without a lieutenant?

Hasler depended upon his ability to work with many different colleagues and graduate students. This strategy was a flexible arrangement that made maximum use of the talents of all involved. Furthermore, his graduate student, Robert A. Ragotzkie (Ph.D. 1953), who had a double major in zoology and meterology, eventually obtained a faculty position in the Department of Meterology. And another of his students, Ross M. Horrall (Ph.D. 1961), was appointed project associate in limnology at the University of Wisconsin in 1965, and later, associate scientist in the Marine Studies Center. Ragotzkie and Horrall's cooperation and advising were important for the growth and vitality of the Wisconsin limnological school.

Hasler also maintained cohesiveness among his students by conducting a weekly seminar, begun about 1948 (and still going strong). The seminar included speakers from both on and off campus. Limnology graduate students were expected to speak before this seminar about their dissertation research, and Hasler treated their presentations as practice sessions for speaking at a scientific society's annual meeting. He also expected his students to attend the weekly seminars held by the Zoology Department.

To advise effectively his large number of graduate students while maintaining his own scientific productivity, Hasler hired able research managers, paid out of research grants. This position, which required a M.S. degree, was held at different times by Henry Eichhorn (1959–1964), James Bruins (1964–1969), Jane Ruck (1970), and David Egger (1970–present). During Hasler's Fulbright year abroad, Warren J. Wisby, who had received his Ph.D. under Hasler the year before (1952), assumed this position, which then carried more responsibility than usual. The Zoology Department also had a full-time mechanic (Frank Eustice at first, later Glen Lee), and between Hasler's grants and the department's resources, funds were sometimes available to hire an electrical engineer, Gerald Chipman. Furthermore, William R. Schmitz (Ph.D. under Hasler, 1958) served as Assistant Director of the Trout Lake Station beginning in 1967.

For special occasions, Hasler obtained special assistance. In 1961 he brought Associate Professor John C. Wright from Montana to help organize the first International Congress of Limnology held in the U.S. In the early 1970s, when Hasler served as Director of the Institute of Ecology, Royce LaNier and Felix Rimberg assisted him for two years, helping assemble specialists to write an evaluation of the status of ecology for the 1972 U.N. Conference on the Human Environment in Stockholm (Workshop on Global Ecological Problems 1972). Nor did Hasler shirk teaching for the sake of his and his students' research. For forty years he taught courses in limnology, ecology of fishes, comparative physiology, field zoology, and second-semester freshman zoology to about 150 students per year (including me in limnology in the fall of 1960).

Soon after Hasler joined the faculty, his interest in the physiology of fish led to experiments conducted jointly with his colleague, Roland K. Meyer, an endocrinologist. They conducted experiments on fish both in the laboratory and in outdoor fish hatchery raceways, always maintaining other fish in controlled conditions. In both of their projects they advanced the time of spawning by injections of carp pituitaries (Hasler, Meyer and Field 1939, Hasler and Meyer 1942). This line of research was not pursued long before being interrupted by World War II. Much later, it would be important for aquaculture, especially in China.

The rise of Nazism and the coming of war were painful for all Americans, but especially so for those with ties to the Germanic people and culture. Hasler's father was the son of Swiss pioneers, but both his father and he spent their Mormon field service (a generation apart) in Germany and Austria. This experience stimulated a permanent interest in the German language and culture, and led Arthur Hasler to become fluent in German. Furthermore, his late wife, Hanna Prüsse Hasler (1908–1969), was from an immigrant German family that retained a high regard for its heritage. When Hasler began lecturing in hydrobiology and in comparative physiology in 1937, he became aware that much of the literature needed by his students was available only in German. While studying this literature, he came to admire the work done by the German zoologist, Karl von Frisch. Von Frisch was an especially brilliant experimentalist (his research eventually won him a Nobel Prize; see Frisch, 1967a, b). When Hasler entered Germany in the spring of 1945 with the U.S. Strategic Bombing Survey, he took the opportunity to become friends with von Frisch in Munich at the partially destroyed Zoologisches Institut, which the Rockefeller Foundation had built for von Frisch before the war (Hasler 1945, 1946). Besides the studies on the language of bees that brought him such fame, von Frisch and his students made fundamental investigations into the sensory physiology of fish. This latter work especially interested Hasler and influenced his own outlook and research.

Another scientist whom Hasler visited during his time away from military duties was Wilhelm G. Einsele at the Anstalt für Fischerei, Weissenbach am Attersee, near Salzburg, Austria. Although all of Einsele's pre-war assistants were casualties of the war, he had managed to carry on his work with the help of women and older fishermen. His primary objective was to increase the productivity of fish in the Attersee and other Austrian lakes. His research had included an attempt to increase the natural phosphate level of a small South German lake (Schleinsee) by adding large quantities of superphosphate (Einsele 1941). This research attracted Hasler's interest, and later he encouraged one of his graduate students to publish a literature review on the "Development and Status of Pond Fertilization in Central Europe" (Neess 1949a).

After five months Hasler returned to the U.S. concerned for the welfare of the biologists whom he had met in western Europe and stimulated by his opportunity to learn first-hand from their work. Although he returned to Wisconsin to pick up his limnological work, there had been enough disruption and stimulation to cause him to reflect upon what he wanted to accomplish as a scientist. There was some momentum left over from the Birge-Juday period and from his own work before 1945 that he could draw upon, but with nothing new to offer in the post-war period, undoubtedly he would have found that momentum quickly spent. It was then, after his own long experiences with experimentation and after having witnessed the experimental work of von Frisch and Einsele, that Hasler realized he wanted to leave his mark on limnology by helping to make it a far more rigorous experimental science than it was in 1945. This approach was already an integral part of his teaching, but in two papers published in 1947 and 1948, he took the opportunity to remind his peers that they should carefully design experiments with controls (Hasler 1947: 391, Hasler and Einsele 1948: 530). It was easy for him to cite published articles showing uncritically designed field experiments, but he found only one showing critical awareness of the problem (Mottley 1942). Some years later he published an article on experimental limnology illustrated with examples from his and his students' work (Hasler 1964).

Although it would be risky to make a strong claim of uniqueness for Hasler's controlled field experiments, it nevertheless seems true that he was unique in seizing upon this approach to limnology as an organizing principle for the program of a limnological school. Such an organizing principle is just what is needed for developing a cohesive scientific school (Crane 1972, Tobey 1981). Good ideas, however, are important only when successfully implemented. How did Hasler use this organizing principle in relation to particular scientists, ideas, and resources to achieve an outstanding scientific school?

Hasler continued the Birge-Juday example of consulting faculty from other sciences concerning research projects, but he depended rather less than they had upon those scientists as active collaborators and rather more upon graduate students in limnology. Hasler supervised the dissertation research of 53 doctoral students and partially directed that of 14 others; he also supervised the thesis research of 41 master's degree students. In this respect, he was following the normal pattern of development for a scientific community, although we may doubt that the leaders of many scientific communities graduate as many students. The limnological ideas that he and his school explored were as diverse as those explored by the school under Birge and Juday. But while the work of Birge and Juday had been narrow in scope to begin with and had gradually expanded, the range of Hasler's interests and competencies were broad from the start. He could therefore attract a range of students who had somewhat different interests from each other. He was able to find some means of support for them while in graduate school and a job when they left.

The financial and material resources available to the Hasler group were substantially better than they had been for the Birge and Juday group, partly because of the cumulative advantages of their earlier activities, but mostly because the country was willing and able to allocate more resources to science after the war than before. However, although more resources became available around 1950, there was competition for them, and any scientist who obtained enough to run a scientific school had to have a research program that was convincing to his peers who allocated the resources. It was a definite help to have momentum already when the National Science Foundation (on the history of the NSF see England 1982), the Federal Water Quality Administration, and the Atomic Energy Commission were established. Before funds from these agencies became available in the 1950s, Hasler and his students obtained research funds from the Graduate School, the Wisconsin Conservation Department, the Office of Naval Research, and several private donors.

Elizabeth Jones (now Mrs. David G. Frey) was the first of Hasler's students whose dissertation topic exemplified the experimental approach of his group. Her task was to investigate whether rooted aquatic vegetation and algae found in the same body of water either compete for nutrients or produce inhibitors. R. N. Pond's experiments (1903) had not indicated any connection, but later observations of algae blooms on Lake Mendota indicated that blooms were not as abundant in years in which the rooted vegetation of the lake flourished. She tested the question in four silos, each 3.6 m in diameter and 1 m deep, which were placed in a large fish hatchery pond (drained, then refilled). Her research was supported with funds (via the Graduate School) from both the Wisconsin Alumni Research Foundation and the Wisconsin Conservation Department. She received her degree in 1947, having found that rooted vegetation does inhibit algae (Hasler and Jones 1949). Although this was a successful example of the Hasler approach to experimental limnology in the field, the silos in the hatchery pond were artificial environments, even if they were outdoors.

The next step would be to conduct experiments in somewhat less artificial environments. Another of his early doctoral students, John C. Neess, investigated the population ecology of the bluntnose minnow (Neess 1949b). Six small identical ponds were dug at the University Arboretum and each was stocked with 12 males and 12 females. This investigation was also experimental limnology, in a sense; the ponds were an experimental situation. However, the reason there were six ponds was to provide data on the range of variation that might develop under similar circumstances. (It turns out there was considerable variation in the colonization of the ponds by plants and also in the rate of increase of the minnows.) Nevertheless, after the ponds were established, there was no attempt to use some as controls and to alter conditions in others.

In 1948 Hasler decided to test on northern bog lakes the possibility that he and Einsele proposed, that dystrophic lakes could be made more transparent if they were alkalized with hydrated lime (1948: 549). Encouraged by Professor Emil Truog in the Department of Soil Science, Hasler tested the suggestion in his laboratory and obtained favorable results. Therefore, it seemed worth trying on a bog lake. Assisting in this project were two graduate students, Oscar Brynildson and William Helm, who would later write doctoral dissertations under Hasler's supervision. They ran their alkalization experiments on Cather and Turk Lakes, on property belonging to Ben McGiveran in Chippewa County. (Probably it would have been difficult to obtain permission to conduct these experiments on state-owned lands.) The experimental plan was to collect limnological and fishery data on these bog lakes for two years before treatment, then replace the resident fish with rainbow and brown trout, treat both lakes with hydrated lime (which, unlike powdered limestone, is readily soluble), and finally to measure the lakes' productivity under the new conditions. The hypothesis was that increased transparency would allow plant growth at greater depths than in the naturally brown humic water, plant growth would increase the dissolved oxygen, and introduced trout would make better use of the new situation for growth than would the original resident species. Their findings supported these assumptions (Hasler, Brynildson and Helm 1951).

Hasler next decided that he needed to use at least one pair of lakes for conducting even cleaner and more tightly controlled experiments within the same season. The ideal example of the Hasler approach was, therefore, the dissertation research of Waldo E. Johnson on Peter and Paul Lakes on Notre Dame University's property in Gogebic County near the Wisconsin state line. These lakes are adjacent and are connected by a narrow neck. If the connection were filled in, two similar lakes could be used, with one (untreated) serving as a reference lake. The use of lakes so far from Madison for dissertation research indicates that experimental limnology is not necessarily a convenient science.

These slightly acid bog lakes seemed ideal for the experiments, and being isolated, were free from incidental public interference. Notre Dame University granted permission to use them and to build an earthen dam across their connecting neck. Using these lakes, one could determine not only the likely importance of some single factor, as in Jones' dissertation, but also the actual importance of the factor upon the life of a lake in nature. For example, Johnson used Peter and Paul Lakes to study the changes produced by alkalization upon rainbow trout productivity (Peter being the treated and Paul the reference lake). He found that productivity increased, because the alkalization of brown-water bog lakes increased the light penetration and stimulated photosynthesis in deep water, hence preventing oxygen depletion at times (especially in winter) when otherwise some of the trout would have died (Johnson and Hasler 1954: 133). His research was supported by grants from the Guido Rahr Foundation and from J. Bruce Allen of Chicago (*ibid.,* 113). Johnson later convinced the Fisheries Research Board of Canada to establish an experimental lake station near Winnipeg, with him as director (Johnstone 1977: 263–269).

Johnson had used these lakes to answer only a limited series of questions relating to fish productivity. Therefore it seemed desirable to have another graduate student use Peter and Paul Lakes to investigate more generally the changes in metabolism of dystrophic lakes caused by the addition of hydrated lime. Raymond G. Stross undertook this project for a doctoral dissertation. Both Johnson and Stross also studied their experimental problems on two or three other lakes to get a broader experience. Stross completed his dissertation in 1958 and the results, that the rate of turnover of the zooplankton was markedly greater in the alkalized lake, were published shortly thereafter (Stross and Hasler 1960). These studies also indicated that lime, presumably an important source of bicarbonate, may be a limiting factor in primary production (see also Hutchinson 1963: 685). The experimental condition established at Peter and Paul Lakes continued in effect under Hasler's auspices for some three decades, after which time bottom sediments could be used to trace the long-range effects of increased light penetration owing to the continued artificial alkalization and enrichment with bicarbonate (Kitchell and Kitchell 1980).

Thus far in discussing the Hasler period of Wisconsin limnology the emphasis has been upon the distinctive aspects of Hasler's methodology and outlook, to illustrate how different the community had become under his direction. Nevertheless, it would not have progressed as rapidly as it did in this new period had he not also utilized the earlier resources. The Trout Lake Station was the most conspicuous of these resources (though not available to him until 1957). Also very important were faculty members who had worked with Birge and Juday and had become experts on aspects of limnology touching their professional teaching and research.

The university administration appointed a faculty Lakes and Streams Committee that functioned from 1952 to 1963. The committee's concern was with water purity in the complex of lakes connected to the Yahara River in the vicinity of the university. Lake Mendota especially was something more than a scenic asset to the university and city and a convenient place to do research. By virtue of having become the most studied lake in the world (Brock 1985), it was now part of America's (and the world's) historical heritage. The coordinator of the committee was bacteriologist William Sarles, and the membership included Hasler in limnology, Gerald Gerloff and F. K. Skoog in botany, Verner Suomi and Reid Bryson in meteorology, Robert Muckenhirn and Marion Jackson in soils, Gerald Rohlich in civil and environmental engineering, and Mel Meloche in chemistry. The committee's accomplishments included working with State Legislator Norman Anderson and law professor Jacob Beuscher on a bill, passed in 1965, to divert sewage from the Yahara drainage basin to the Nine Springs Treatment Plant. Hasler also served for many years on Madison's Lake Mendota Problems Committee (Threinen 1968). By taking an active part in such committees, Hasler built relationships with both older and newer faculty members. These relationships were important for advancing such an interdisciplinary subject as limnology.

As stimulating as he found some of his interactions with colleagues in related disciplines at Madison, it had been even more stimulating for Hasler to interact with European authorities on subjects in which he was directly involved. He decided, therefore, that it was important to bring to Madison for lectures and discussions such authorities from both Europe and North America. Among the first of them was Karl von Frisch, who came in 1949 and whose memories of the trip are included in his autobiography (1967a: 165–166). Another was C. H. Mortimer, who was a visiting professor in Madison in 1962–1963 and who came back to the University of Wisconsin-Milwaukee in 1966 as Distinguished Professor of Zoology and first Director of the Center for Great Lakes Studies. By 1962, Hasler was bringing in between six and fifteen per year. Many of them were brought in with funds from the Federal Water Quality Administration. In addition to these distinguished guests, Hasler was also able to arrange for young limnologists from Europe and Asia to come and work with him in Madison. These post-doctoral students not only carried back with them insights gained from the Wisconsin limnological community, they also left behind the stimulating influence of their knowledge and perspective, contributing thereby to the sophistication of all those involved.

It was equally important, both to Hasler and his students, that he continue to travel to distant places to broaden his knowledge of limnology and fishery biology. He took short trips at various times to Lake Tahoe, Crater Lake, Hawaii, and Point Barrow in the U.S., to Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia in Canada, and abroad to U.S.S.R. (including Siberia), China, Japan, Eniwetok Atoll, Bikini, Argentina, Brazil, Guyana, Mexico, Puerto Rico, Costa Rica, Guatemala, England, France, Spain, Portugal, Netherlands, Poland, East and West Germany, Finland, Scandinavia, Iceland, Italy, Yugoslavia, Czechoslovakia, Romania, Ghana, and Israel. He returned from these refreshing trips with many valuable ideas.

In 1953 Hasler was awarded a Fulbright Research Scholarship that enabled him to go, with his wife and their six children, to the University of Munich for the academic year 1953–1954. There he conducted research in association with von Frisch. It was from von Frisch's strong interest in the physiology and behavior of fish that Hasler hoped to benefit. Hasler brought with him several years of his own experimental knowledge on the sense of smell in fish, and now he wished to expand his understanding of the ways fishes perceive their environment.

It was appropriate that he return to Munich for some of this work, because his earlier acquaintance with von Frisch and his researches played a role in getting Hasler interested in doing research on this subject. In 1946, the year following his visit to occupied Germany, Hasler had returned to his hometown of Provo for a vacation. This was a chance to indulge once more in two favorite hobbies of his youth—hiking the trails and fishing the streams of the Wasatch Mountains. As he climbed the eastern slope of Mt. Timpanogos, he pondered the question of how salmon find their way back to their home stream to spawn. His thoughts were momentarily interrupted by a homing experience of his own: "I approached a waterfall which was completely obstructed from view by a cliff; yet, as a cool breeze, bearing the fragrance of mosses and columbine, swept around the rocky abutment, the details of this waterfall and its setting on the face of the mountain suddenly leapt into my mind's eye. In fact, so impressive was this odor that it evoked a flood of other boyhood associations, long since vanished from conscious memory." If the smell of his boyhood haunts evoked such a strong memory association in him, perhaps it did the same for salmon; here was a hypothesis worthy of investigation (Hasler and Scholz 1983: xi–xiii). Later, when he recalled this experience, he appreciated the observation made by Louis Pasteur in his opening speech to the Faculte des Sciences at Lille, 7 December 1854: "chance only favours the prepared mind" (Vallery-Radot 1923: 79).

Hasler's serendipitous experience on Mt. Timpanogos led to his most important line of research. But was his idea for this research based upon a fortuitous impression, or is the parallel between fish and human memory real? The range of childhood experiences in humans is so vast that this would be a difficult question to answer scientifically. However, if someone else unaware of Hasler's experience reported a similar one, this would strongly support the possibility of his experience representing a parallel capacity in fish and humans. I have found such a report in Wallace Stegner's *Wolf Willow: A History, a Story, and a Memory of the Last Plains Frontier* (1962: 17–21). Stegner (b. 1909) grew up along the Frenchman River in southern Saskatchewan, and he returned to his childhood haunts after several decades to experience again memories of the region. One memory in particular haunted him, associated with the river bank where he once swam and fished. Returning to the spot did not satiate his quest until he smelled once more the odor which he earlier associated with the place—an odor he discovered coming from the flowers of a shrub along the bank, wolf willow.

Are salmon guided by the memory of smell when they return from the sea to their home stream to reproduce? It is a question presumably susceptible to a "yes" or "no" answer. Yet, for Hasler, it was a question that led to a lifetime of research, and not just for himself. Among the essential characteristics of a leader of a scientific school is the ability to establish a meaningful research program for himself and others in the school. This subject became the most important of the various research themes developed at the Wisconsin limnological school under Hasler's direction. It is appropriate, therefore, to follow it in more detail than the others, to see both what was learned and how the school worked.

If Hasler had been teaching in a western university, perhaps he would have begun work immediately upon salmon. Being located in Wisconsin, however, he wondered if his question might not be clarified, at least in part, by some initial studies on other species. If salmon are guided by odors, perhaps some common Wisconsin fish, such as the bluntnose minnow *(Pimephales notatus)*, might be also. It was worth an investigation, and probably worth a doctoral dissertation for an interested graduate student. Theodore J. Walker (Ph.D., 1948) was one who was interested, and he studied the capacity of this minnow to discriminate between the odor of water-milfoil *(Myriophyllum exalbescens)*, common hornwort *(Ceratophyllum demersum)*, and 12 other species. Hasler and Walker sought the assistance of Wisconsin faculty in psychology concerning experimental apparatus, experimental design, and measurements having statistical significance. Walker found that he could, in 2.5 months, train his fish to distinguish the odors of these plants.

The fish obtained food—positive conditioning—when it went toward the odor of one species, but an electrical shock—negative conditioning when it went toward the odor of a second species (Walker and Hasler 1949).

These findings were encouraging, but there is a great leap between showing that a minnow can discriminate between two plant odors and claiming that salmon use odors for homing. The next step in bridging this gap was to show that bluntnose minnows can discriminate between the odors of different streams. Warren J. Wisby, who had written his M.S. thesis under Hasler on "Techniques for Investigating the Ecological Aspects of the Behavior of Fishes" (1950), undertook this research for a doctoral dissertation (Ph.D. 1952). Norman Fassett advised on the selection of two streams near Madison, Otter and Honey Creeks, that had strikingly different water chemistry, soils, and plant communities. The minnows were then trained in an experimental situation similar to that used by Walker. Later Hasler explained the influence of these streams on fish as analogous to the differences in aroma and taste to humans of wines made from grapes grown on different soils and in different climates. Wisby found that in two months he could train his minnows to distinguish between the waters of the two streams. Then when the olfactory sacs of trained fish were destroyed the fish no longer distinguished between these waters, which proved that smell rather than taste supplied the cue. Experiments using chemical fractionations of the component parts of the waters indicated that the minnows were responding to a volatile, organic substance in the waters. These experiments were also later done successfully on salmon (Hasler and Wisby 1951: 224).

But did the capacity of fish in nature to discriminate odors equal their capacity to do so in the laboratory? Would salmon with occluded nasal chambers make the same choice of a breeding stream as they made with normal olfactory chambers? Only a test of salmon in nature would answser satisfactorily the latter question. Wisby and Hasler, with the collaboration of Lauren R. Donaldson from the University of Washington, captured salmon above the junction of the Issaquah Creek and East Fork of Issaquah Creek (east of Seattle). Half of those captured were tagged as controls, and the other half were tagged as experimental fish in which the olfactory sacs were plugged with vaseline-coated cotton. All fish were then trucked downstream well below the junction of the creek. Most of those with normal olfaction swam back up the stream of their previous choice, but those with occluded "noses" were as likely to choose one stream as the other. "The results, therefore, are in accord with those which would be expected if the fish were relying on their sense of smell in making this choice" (Wisby and Hasler 1954).

The success of all these investigations indicated that Hasler's hunch was on the right track—the organic odors of each stream were different. He therefore wrote a comprehensive physiological monograph on "Odour Perception and Orientation in Fishes" (1954) and, for the more general audience of *Scientific American,* "The Homing Salmon" (Hasler and Larsen 1955).

Yet, even though Hasler's hunch about the salmon's selection of a stream being controlled by odor seemed correct, he came to realize that this could not be the whole story. Stream odors might be the cue for salmon to recognize their home river, but how did they find their way back to the correct river after several years at sea? Something else must be operating in this segment of their homing. Use of the sun for orientation was a possibility that came to his mind—its importance for migrating birds was already under investigation (Griffin 1952: 382–384, Kramer 1953). Hoping to investigate this possibility, Hasler sought a Fulbright Research Scholarship for the 1953–1954 academic year to work in Munich with von Frisch and to visit Gustav Kramer in Wilhelmshafen. They were both doing exciting work on the use of the sun for orientation, the former working with bees and the latter with birds. Hasler also visited Konrad Lorenz at Buldern bei Dulmen. In Munich Hasler found that the common European minnow, *Phoxinus laevis,* could orient itself toward a lamp (simulating the sun) in a laboratory setting in order to obtain food, even when other environmental factors were varied randomly (Hasler 1956a).

After that stimulating year abroad, he returned to Madison pondering further questions concerning sun orientation. Could fish be trained to orient themselves when the lamp was moved around the room to simulate the apparent movement of the sun across the sky during the day? Could a capacity for sun-compass orientation also be demonstrated in fish in a natural environment? These questions would be answered affirmatively in an article that is especially interesting from our standpoint of illustrating a scientific community in action. The leader of an effective group must be able to raise significant, but solvable, questions that will keep both him and his associates productively occupied. These two questions are both on fish orientation, yet one falls within the domain of the laboratory and the other within the domain of field studies. In practice, few scientists are as active as Hasler has been in both domains; by inclination most will pick one or the other as their preference, and their imagination will then operate primarily on questions raised within that domain.

Hasler was aware of this tendency, and as collaborators on this project he had Wisby (then a "postdoc"), who as a graduate student had worked under him in both laboratory and field, Ross M. Horrall, a graduate student whose inclinations ran toward field research, and Wolfgang Braemer, a German behavioral physiologist whose inclination for laboratory research was influenced by his loss of a leg in World War II. Horrall's initial experiments on homing in white bass in Lake Mendota (Hasler *et al.* 1958) were continued for his doctoral dissertation (Ph.D. 1961). Braemer's experiments on sun-compass orientation formed the basis for "A critical review of the sun-azimuth hypothesis" (Braemer 1960). Even that was not to be the end of this line of research. Hasler started another graduate student, Horst O. Schwassmann (whom he had met in Germany before Schwassmann immigrated to Milwaukee), on the study of sun-compass orientation in fish native to different latitudes. Schwassmann and Hasler trained fish in Madison, then moved them to a different latitude (on the equator in Brazil) and attempted to retrain them. This work was far enough along in 1960 for them to report preliminary results at the Cold Spring Harbor Symposium on biological clocks (Hasler and Schwassmann 1960), and Schwassmann continued this research for his doctoral dissertation (Ph.D. 1962).

To discover whether they returned home by random or directed swimming, Hasler and Horrall tracked the movements of displaced white bass in Lake Mendota by attaching floating plastic balls to the fish with a nylon thread and fish hook (illus. in Hasler 1963: 66, Hasler 1966a: 88). This technique was adequate for the small-scale study in Lake Mendota, but was unsatisfactory for tracking salmon because the float interfered with the speed and changes in depth of the fish. Hasler assigned the task of developing a more flexible tracking technique to another graduate student, H. Francis Henderson. With assistance from Gerald Chipman, an electronics engineer, Henderson developed a sonic transmitter that could be inserted into a fish's stomach or abdomen and could transmit signals up to 200 m for about 15 hours (Hasler and Henderson 1964, Hasler 1966: 128–129). This research was sufficient for Henderson's dissertation (Ph.D. 1963) and secured his appointment to the faculty in the Zoology Department.

By 1963 Hasler, his students, and research associates had studied the homing abilities of fish from enough different perspectives for him to develop a comprehensive synthesis of their findings. He found the time to write *Underwater Guideposts: Homing of Salmon* during a semester spent at the University of Helsinki as a Distinguished Exchange Professor. This book, which appeared in 1966, was an important milestone for him as a scientist and as the leader of an important scientific community. Many scientists devote their entire career to the elucidation of various narrow questions and never publish a comprehensive synthesis. Such had been the case with Birge and Juday. They had achieved prominence by virtue of the high quality and vast quantity of their work. They had explored many aspects of limnology, but for a synthesis, they depended upon the attention their work received in such textbooks as *The Life of Inland Waters* (1916; 2nd ed., 1930; 3d ed., 1937) by the Cornell limnologists James G. Needham and J. T. Lloyd and *Limnology* (1935) by Paul S. Welch of the University of Michigan. Because there had been only a few competing communities of limnology, their work did receive due attention. Hasler, however, worked in a far larger arena, where the approach of Birge and Juday would have attracted far less notice than it had in their day. Hasler's book provided a convincing and detailed answer to a long-standing puzzle: how could salmon swim out into a vast, trackless ocean and yet return to the stream of their birth to spawn? The book is also a more prominent record of the most important achievement of the Wisconsin limnological school under his direction than were individual scientific papers. It illustrates the use of experimentation in both laboratory and field for solving limnological problems.

Even if Hasler did not, after that, merely rest on his laurels, there were so many different subjects under investigation at the Laboratory of Limnology by 1966 that one might expect that the subject of salmon homing would have been dropped—after all, it had been done. Furthermore, both the Atlantic and Pacific salmon live a long way from Madison; it would be more convenient and practicable to study problems that could be solved within the state of Wisconsin. However, at about the time that such thoughts were going through Hasler's head, "the Departments of Natural Resources in Michigan and Wisconsin introduced coho salmon into the Great Lakes to feed on and thus reduce the alewife population and to revitalize the Lake Michigan fishery" (Hasler and Scholz 1983: xv). The coho flourished—to the delight of sports fishermen—and thus provided an opportunity to answer questions still lingering from earlier investigations and also new ones arising from the management of salmon in the Great Lakes. Hasler's decision to exploit this unexpected opportunity was another example of "chance favoring the prepared mind."

The primary question that intrigued him was how olfactory imprinting occurred in young salmon. At the end of their paper on "Discrimination of stream odors by fishes and its relation to parent stream behavior" Hasler and Wisby had suggested the experiment of "exposing salmon to a constant, artificial odor through the fingerling stage and then determining if the fish conditioned in a hatchery could be decoyed to a neighboring stream upon return from the sea" (1951: 237). Neither they nor apparently anyone else had actually tried it, but twenty years later it was an experiment that could be tried in rivers flowing into Lake Michigan. Some of Hasler's graduate students in the 1970s—Andrew E. Dizon (M.S. 1966, Ph.D. 1971), John C. Cooper (Ph.D. 1974), Peter J. Hirsch (Ph.D. 1977), Peter B. Johnsen (M.S. 1976, Ph.D. 1978), Allan T. Scholz (M.S. 1977, Ph.D. 1980)—collaborated with him and Horrall in designing and carrying out experiments on salmon imprinting. They raised thousands of salmon, mostly inland in

Wisconsin hatcheries, imprinted them to morpholine, and later released them in Lake Michigan. When sexually mature, they began to search for their home stream. Morpholine was then used to scent one of the rivers. The number of imprinted salmon, distinctively marked, returning at sexual maturity to the scented stream was ten times greater than the number of controls returning to the stream. Another chemical, phenethyl alcohol, worked equally well in another series of duplicate experiments. These experiments were repeated several times to establish their validity.

There were as many as seven co-authors to some of the papers published by this group working on salmon homing in Lake Michigan in the 1970s. All of their work was finally collected and synthesized in Hasler and Scholz's book, *Olfactory Imprinting and Homing in Salmon* (1983 with references). The work of this group has not only broadened and deepened our understanding of salmon physiology and ecology, it has also provided the key insights needed to transform the salmon fishery from a wild one of modest value into an invaluable domestic one (Hasler and Scholz 1978, 1980, Thorpe 1980, Donaldson and Joyner 1983). Furthermore, their work has been singled out as a model of a rigorous experimental method applied to a field problem in biology (Baker and Allen 1982: 14–19).

This work on salmon is atypical of a limnological school. Textbooks on limnology frequently have little or nothing to say about fish—a ridiculous bias, in Hasler's opinion. However, in his effort to redress that omission, he did not err in the other direction and neglect the more typical preoccupations of the limnologist. His own article, ''Wisconsin, 1940–1961'' (1963) is an ample survey of all aspects of limnology pursued at the University of Wisconsin under his leadership, and other examples of research conducted by Hasler and his students are provided in preceding chapters. One emphasis of the Wisconsin school under Hasler was on limnological research during the winter. Birge and Juday had taken a few winter measurements, mostly in Madison, but no one before Hasler had conducted so many winter studies. Twenty-two of his 195 published papers report on research performed in severe winter conditions, many at northern lakes far from Madison.

The Birge-Juday community existed for almost forty years and the Hasler community slightly more than forty years. The two periods are thus comparable in duration, and this invites a comparison in achievement. The Hasler community seems to have been more productive and more influential than was the Birge-Juday community. This is, of course, what one would expect, because science has been better supported since 1940 than it was previously, and a larger number of Americans have been active scientists since that date than before. Limnology has grown along with other sciences, and the Wisconsin story reflects that. On the other hand, competition for science resources, students, and honors has also increased with the increase in the number of active scientists. For example, regardless of how rapidly the American Society of Limnology and Oceanography has grown, only one member is honored each year with its presidency. Thus, it would be surprising if limnology in America had not grown steadily during the period in which Hasler headed the Wisconsin group, but all of that growth could have occurred on other campuses. It was only because Hasler seized the opportunities that so much of the growth in American limnology continued to occur at Wisconsin.

Publications are lasting indicators of scientific achievements, but other measures are also important. Students are one, and the 41 who received their M.S. degree and the 53 who received their Ph.D. degree under Hasler's direction are impressive indicators of success. Although some of these students were supported in part by teaching or research assistantships, a scientific school cannot achieve distinction unless it attracts research funds. For his time, Birge was notably successful in this respect, and Hasler was even more so. The record of this success, discussed to some extent earlier in this chapter, is found in the acknowledgments of the theses and publications coming from this community.

Another measure of academic success, so dear to the heart of administrators, are university buildings. Birge had established the Trout Lake Station, although it was housed in very modest wooden structures. Michael Guyer had also used university funds to build the small lab on Lake Mendota, first used under Hasler. However, Hasler and associated faculty and research assistants had to retain offices in Birge Hall, because their lab at the end of Park Street was too small to hold offices. This inconvenience was compounded by the fact that the limnological school was essentially an informal subdivision of the Department of Zoology. Although Hasler served as chairman of that department in 1953 and again from 1955 to 1957, whenever new needs arose in limnology, they had to be evaluated within the competing needs of the department as a whole. Sometimes the needs of this growing field had to be deferred to the needs of some discipline that attracted fewer students (its equipment could still become obsolete) because the latter had already waited a long time to have its needs met.

A way around this impediment came in 1962, when Hasler obtained funds from the National Science Foundation to build a new Laboratory of Limnology on the shore of Lake Mendota. Because he had obtained the NSF funds, Hasler was given the initiative to choose the site, the general plan for the building, and the architect. He was already acquainted with Albert Gallistel, Superintendent of Buildings and Grounds, from their long association on the Arboretum Committee. Hasler knew that Gallistel shared his concern for landscape architecture and environmental quality. They agreed on a site west of the Memorial Union, near the Hydraulics Lab. By placing it there, they prevented an automobile road from being built along the lake (as opposed to the bike and foot path that is still there). In 1957 Hasler and a few colleagues had led the faculty opposition that had saved the view from the Union becoming a 600-car parking lot—advocated by university regent Oscar Rennebohm and approved by President E. B. Fred— by convincing the faculty and its parking committee that the lake was too sacred to the university and to science to be desecrated by the contemplated landfill.

The general concept for the cantilevered laboratory was sketched by Mrs. Holger Jannasch, a German architect who spent a year in Madison with her husband, a postdoctoral fellow and an eminent marine and freshwater microbiologist. Hasler chose William Kaeser, a Madison architect, to develop her plan in detail, and in 1963 Hasler proudly described it in the *American Zoologist* (p. 339):

> An attractive formed-concrete building cantilevered over the waters of Mendota has recently been completed. The new Laboratory of Limnology provides offices, laboratories, conference rooms, a library, and supporting facilities for a staff of 35 people, as well as adequate fish-holding and storage facilities. The basement level encloses a boat slip opening to Mendota between concrete entrance piers. A large shop, rooms for gear and boat storage, fish holding tanks, small rooms for recording instruments, motors, and batteries, and a shower room with locker facilities complete the lower floor.
>
> The first floor includes laboratories for graduate students and visiting personnel, for paleo- and latitudinal-limnology, hydrobotany, and microbiology. A dark room, culture room, isotope room, instrument room, and chemical laboratory are also included. The second floor consists of laboratories for the study of the behavior and physiology of fishes, zooplankton and

benthos, physical limnology, and fishery biology. Offices of the director, secretaries, a library, large aquarium room, graduate laboratories, and offices for investigators are welded into a working unit. The laboratory was designed not only for the needs of the students and faculty, but also to meet those of visiting investigators.

Because of his success in obtaining NSF funds for this laboratory, the university later asked him to try to obtain funds for a sorely needed laboratory at the Trout Lake station. He agreed to try, providing the university this time put up half the money; it did, and he obtained the other half from NSF in 1966.

Hasler remained head of the Laboratory of Limnology from its opening in 1963 until his retirement—from formal duties, at least—as Professor Emeritus in 1978. Occasionally administrative posts interested him but did not come his way. In retrospect, he is glad they did not, because administrative responsibilities would have interfered with his salmon research, for which he has received so much enthusiastic recognition, both nationally and internationally. He has maintained membership in 19 professional societies and held various offices in a number of them, including president of the American Society of Limnology and Oceanography (1949–1950), Ecological Society of America (1961), American Society of Zoologists (1971), International Association for Ecology (1967–1974), and of the latter Association's First Congress (The Hague, 1974). He has been elected to membership or honorary membership in a number of scholarly organizations, both here and abroad, including the prestigious National Academy of Sciences (1969) and the American Academy of Arts and Sciences (1972). In 1977 the American Fisheries Society honored him with its Award of Excellence. In 1980 both the American Institute of Biological Sciences and the Sea Grant Association presented him with distinguished service awards.

One might suppose that, as a past president of both the American Society of Limnology and Oceanography and the Ecological Society of America, Hasler's greatest professional involvements would be with one or both of those societies. Since joining the National Academy of Sciences, however, that organization has been the main focus of his scientific activities. He was proud of the fact that, when elected, only he and one other limnologist, G. Evelyn Hutchinson, were members of that august body of 900 senior scientists. He assisted in writing two of its reports for 1969, *Resources and Man* (269 pp.) and *Eutrophication: Causes, Consequences, Correctives. Proceedings of a Symposium* (661 pp.). Other National Academy of Sciences reports he helped prepare are entitled: *Biology and the Future of Man* (1970) and *Rehabilitation Potential of Western Coal Lands* (1974).

By every standard of scientific success, Hasler has been acknowledged by his peers as a leading scientist and the head of a leading scientific school. He has always enjoyed the involvements and interactions that his successes have brought, but he has also resisted the temptation to "wheel and deal" just for ego satisfaction. That is a trap that, among other things, leads to the neglect of one's students. Although Hasler demanded high levels of performance from his students, in return he gave generously of his time, thoughts, and efforts. One student, Scholz, remembered "his cussedness and refusal to give up in the face of adversity during a bout with colon cancer in 1971–1972." The 53 students who had received doctorates under him showed their appreciation by returning to Madison for a commemorative celebration when he retired in March, 1978. They also commissioned a composition in his honor, a quartet for horn and strings by David Diamond of the Juliard School of Music. This idea came from their awareness that, for 25 years, Hasler had played horn for the Madison Civic Symphony. The premier performance was by the Pro Arte Quartet in Madison in October, 1978, with Douglas Hill as hornist.

A further recognition of his achievement as head of an outstanding school of limnology was the large drawing of his academic "genealogical tree" by Kandis K. Elliot in 1978. This chart is an imaginative and thoughtful display of the history of the Wisconsin limnological school under his direction, as revealed by the master's and doctor's degrees of his students. It hangs in the Laboratory of Limnology.

When Hasler retired in 1978 and turned over the Center for Limnology to his colleague, John J. Magnuson, he, like Birge and Juday after 1937, continued his professional activities. Because those activities have enhanced the reputation not only of himself, but also of the limnological school, it is relevant to give some indication of them. In 1981 he submitted to the National Academy of Sciences (NAS) a proposal, "Salmon for Peace in the North Pacific," for a cooperative program of salmon ranching to be undertaken by the Soviet Union, the People's Republic of China, and Japan. The proposal includes the establishment of hatcheries, the use of artificial imprinting, and the restocking of the Amur (Heilong) and Wusuli (Ussuri) Rivers along the China-U.S.S.R. border. In 1983 the Chinese Fisheries Society, intrigued by the proposal, invited him to China under auspices of the NAS Distinguished Scholar Exchange Program. Hasler accepted the invitation and traveled around that country explaining his plan and also giving more general lectures and advice on limnology and fishery biology. He was received by very enthusiastic audiences. In 1984, because there are good prospects for developing a valuable fishery, the Soviet embassy requested that he evaluate a plan for international collaboration (Hasler 1984), and he also traveled to the U.S.S.R. as a NAS Distinguished Scholar for six weeks in 1986.

Conclusions

The history of a scientific community appears to be a very good way to present the history of modern ecology. By its nature ecology is a science that has imprecise boundaries, and any historical study should have a plausible way to delimit its scope. Ideally, history of science should include both substantive history of achievements and the circumstances under which the scientists worked. The history of a scientific community permits the presentation of both. In this case the focus is on the contrasting development of the limnology community at the University of Wisconsin under the leadership first of Birge and Juday and then of Hasler.

Birge and Juday were intent upon doing limnology, not upon developing a scientific school. Although there were theoretical aspects of their work, no elaborate scientific theory guided their endeavor. They achieved leadership in American limnology by virtue of the quality and quantity of their descriptive limnology. Their limnological community developed slowly and was really a by-product of their efforts to expand the number of scientists involved in their research. It might have been limited to their colleagues had Juday not gotten bumped from the Wisconsin Geological and Natural History Survey during the Depression, which led to his full-time appointment as a professor of zoology with graduate students. While they imparted to their students some of the skills and perspective needed by competent scientists, their primary objective remained the production of limnological knowledge, not the running of a scientific school.

Hasler was one of Juday's 13 doctoral students, but his work under other biologists at the university was as important to him as his limnological training under Juday. Both as a student and later as a faculty member Hasler compared his experience in the Wisconsin limnological community under Birge and Juday with what went on elsewhere in the university, and he decided that he should offer his students a richer experience than he had received. Furthermore, whereas they had started out as zoologists and had only gradually developed broader interests in the aquatic environment, Hasler's interests were very broad from the time he arrived in Wisconsin from Utah. In addition, he also had a methodological commitment—even a mission—that guided much of his pioneering work and his teaching. He set for himself high standards of performance in teaching, research, and service to university, community, and profession. Remarkably, he was able to maintain that commitment for more than four decades. Those Mormon values of his childhood had been good enough for a lifetime. Hasler handed over to Magnuson a much stronger limnology program than he had received.

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Appendix

Ph.D. Students with Chancey Juday

Bennett, George W.
1939. Ph.D. Limnological investigations in Wisconsin and Nebraska. I. The limnology of some gravel pits near Louisville, Nebraska. 63 p. II. The growth of the large mouthed black bass, *Huro salmoides* (Lacépède), in the waters of Wisconsin. III. Growth of the small-mouthed black bass, *Micropterus dolomieu* (Lacépède), in Wisconsin waters.

Bere, Ruby.
1932. Ph.D. the bacterial content of some Wisconsin lakes. 27 p. The effect of freezing on the number of bacteria in ice and water from Lake Mendota. 18 p. Copepods parasitic on fish of the Trout Lake region, with descriptions of two new species.

Frey, David G.
1940. Ph.D. Growth and ecology of the carp, *Cyprinus carpio* Linnaeus, in four lakes of the Madison region, Wisconsin. 248 p.

Hasler, Arthur D.
1937. Ph.D. The physiology of digestion of plankton Crustacea. I. Some digestive enzymes of *Daphnia*. II. Further studies on the digestive enzymes of A. *Daphnia* and *Polyphemus,* B. *Diaptomus* and *Calanus.*

Morrison, J. P. E.
1931. Ph.D. A report on the Mollusca of the northeastern Wisconsin lake district. Studies on the life history of *Acella haldemani* ("Desh." Binney).

Pennak, Robert W.
1938. Ph.D. The ecology of the psammolittoral organisms of some Wisconsin lakes, with special reference to the Tardigrada. Copepoda, and Rotaroria. 180 p.

Schloemer, Clarence L.
1939. Ph.D. The age and rate of growth of the bluegill, *Helioperca macrochira* (Rafinesque). 113 p.

Schneberger, Edward.
1933. Ph.D. The growth of yellow perch (*Perca flavescens* Mitchell) from Nebish, Silver and Weber lakes in Vilas County, Wisconsin. 73 p.

Spoor, William A.
1936. Ph.D. The age and growth of the sucker. *Catostomus commersonii* (Lacépède), in Muskellunge Lake, Vilas County, Wisconsin. 90 p.

Tressler, Willis L.
1930. Ph.D. Limnological studies of Lake Wingra. 35 + v p.

Wiebe, Abraham H.
1929. Ph.D. Productivity of fish ponds. I. The plankton. 95 + ii p.

Wimmer, Edward J.
1928. Ph.D. A study of two limestone quarry pools.

Wright, Stillman.
1928. Ph.D. Studies in aquatic biology. I. A chemical and plankton study of Lake Wingra. 35 p. II. A revision of the South American species of *Diaptomus*. III. A contribution to the knowledge of the genus *Pseudodiaptomus*.

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Allsopp, Herbert W.
1949. M.S. No thesis.

Andrews, Jay D.
1946. Ph.D. The macroscopic invertebrate populations of the larger aquatic plants in Lake Mendota. 104 p.
Armitage, Kenneth B.
1954. Ph.D. The comparative ecology of the riffle insect fauna of the Firehole River, Yellowstone Park, Wyoming. 50 p.
Bardach, John E.
1949. Ph.D. Contribution to the ecology of the yellow perch (*Perca flavescens* Mitchell) in Lake Mendota, Wisconsin. 74 p.
Batha, John.
1966. M.S. Observations on movements of freshwater mussels. 43 p.
*Baumann, Paul C.
1972. M.S. Distribution, movement, and feeding interactions among bluegill and three other panfish in Lake Wingra. 48 p.
Becker, George C.
1951. M.S. No thesis.
*Bjerke, John.
1962. M.S. The use of ribonucleic acid in zooplankton as an index of biological productivity in freshwater lakes. 80 p.
*Bott, Thomas L.
1968. Ph.D. Ecology of *Clostridium botulinum* type E. 85 p.
Brynildson, Clifford.
1950. M.S. No thesis.
Brynildson, Oscar M.
1958. Ph.D. Lime treatment of brown-stained lakes and their adaptability for trout and largemouth bass. 191 p.
Budd, John C.
1950. M.S. No thesis.
Chidambaram, S.
1972. Ph.D. Hormonal regulation of pigmentation, glycemia and natremia in the black bullhead, *Ictalurus melas.* 158 p.
Cooper, Jon C.
1974. Ph.D. Olfactory imprinting and memory in salmonids. 137 p.
Dizon, Andrew E.
1966. M.S. The scoptic spectral sensitivity of the white bass, *Roccus chrysops.* 22 p.
1971. Ph.D. Ecological aspects of the evoked olfactory bulb electroencephalograph of fish with special reference to homing behavior in salmon. 168 p.
Doepke, Philip A.
1963. M.S. Arsenic distribution in a shallow lake treated with an herbicide of sodium arsenite.
1969. Ph.D. An ecological study of the walleye, *Stizostedion vitreum,* and its early life history. 202 p.
Dugdale, Richard C.
1952. M.S. No thesis.
Dunst, Russell C.
1970. M.S. The effect of stream flow upon brown trout in Black Earth Creek, Wisconsin. 34 p.
Faber, Daniel J.
1963. Ph.D. Larval fish from the pelagial region of two Wisconsin lakes. 122 p.
*Fee, Everett J.
1972. Ph.D. A numerical model for the estimation of integral primary production and its application to Lake Michigan. 169 p.
Gallepp, George W.
1974. Ph.D. The behavioral ecology of larval caddisflies, *Brachycentrus americanus* and *Brachycentrus occidentalis.* 169 p.

Gammon, James R.
1957. M.S. A comparative study of the northern pike and the muskellunge. 42 p.
1961. Ph.D. Contributions to the biology of the muskellunge. 144 p.
Gasith, Avital.
1974. Ph.D. Allochthonous organic matter and organic matter dynamics in Lake Wingra. Wisconsin. 209 p.
*Haase, Bruce L.
1969. Ph.D. An ecological life history of the longnose gar. *Lepisosteus osseus* (Linnaeus), in Lake Mendota and in several other lakes of southern Wisconsin. 224 p.
Hazelwood, Donald H.
1954. M.S. No thesis.
Helm, William T.
1958. Ph.D. Some notes on the ecology of panfish in Lake Wingra with special reference to the yellow bass. 88 p.
Henderson, H. Francis.
1963. Ph.D. Orientation of pelagic fishes. I. Optical problems. II. Sonic tracking. 132 p.
Hergenrader, Gary L.
1967. Ph.D. Echo sounder and sonar studies of the diel and seasonal movements of pelagic lake fishes. 194 p.
Hirsch, Peter J.
1977. Ph.D. Conditioning the heart rate of coho salmon *(Oncorhynchus kisutch)* to odors. 82 p.
Holt, Charles S.
1962. M.S. The influence of physical characteristics of substrates of stream bottoms on repopulation of denuded areas by macroinvertebrate organisms. 61 p.
Horrall, Ross M.
1961. Ph.D. A comparative study of two spawning populations of the white bass, *Roccus chrysops* (Raf.), in Lake Mendota, Wisconsin, with special reference to homing behavior. 181 p.
*Howmiller, Richard P.
1966. M.S. No thesis.
1971. Ph.D. The benthic macrofauna of Green Bay, Lake Michigan. 225 p.
Hunt, Robert L.
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Hunt, John R.
1958. M.S. Progress report on the behavior of net avoidance in fish. 20 p.
1962. Ph.D. The utilization of the nests of *Lepomis cyanellus* by *Notropis umbratilis.* 138 p.
Huver, Charles W.
1961. M.S. Variation and speciation in coregonid fishes. 27 p.
Jaeger, James W. A.
1972. M.S. The effect of different weather conditions on the feeding of northern pike, *Esox lucius.* 80 p.
John, Kenneth R.
1954. Ph.D. An ecological study of the cisco, *Leucichthys artedi* (LeSueur), in Lake Mendota, Wisconsin. 121 p.
Johnsen, Peter B.
1976. M.S. Handbook of aquatic biotelemetry.
1978. Ph.D. Contributions on the movement of fish: I. Behavioral mechanisms of upstream migration and homestream selection in coho salmon *(Oncorhynchus kisutch).* II. Winter aggregations of carp *(Cyprinus carpio)* as revealed by ultrasonic tracking.
Johnson, Waldo E.
1954. Ph.D. Dynamics of fish production and carrying capacity of some northern soft-water lakes. 51 p.

Jones, Sara E.
1947. Ph.D. An ecological study of large aquatic plants in small ponds. 166 p.
*Judd, John H.
1969. Ph.D. Effect of salt runoff from street deicing on a small lake. 145 p.
Kaya, Calvin M.
1967. M.S. Effects of temperature on nesting and gonadal development of *Lepomis macrochirus* (Rafinesque) and *Lepomis cyanellus* (Rafinesque). 49 p.
1971. Ph.D. Relation of the annual reproductive cycles of the green sunfish. *Lepomis cyanellus* (Rafinesque) to seasonal changes in temperature and photoperiod. 193 p.
Kingsbury, A. P.
1966. M.S. Discrimination of lake water odors by the white bass, *Roccus chrysops* (Rafinesque). 72 p.
Koonce, Joseph F.
1969. M.S. Estimations of phytoplankton production and biomass in a small acid bog lake. 63 p.
1972. Ph.D. Seasonal succession of phytoplankton and a model of the dynamics of phytoplankton growth and nutrient uptake. 192 p.
Kunny, Bartholomew K.
1967. Ph.D. An analysis of the distribution of the macroscopic riffle fauna in 32 small streams in the southern half of Wisconsin and some of the interdependent ecological factors affecting this fauna. 200 p.
Le Cren, E. David.
1947. M.S. No thesis.
Lenz, Andrew N.
1965. M.S. Studies on diversity and respiration of periphytic bacteria in a thermal river system. 23 p.
Likens, Gene E.
1959. M.S. Exchange of elements across the chemocline of a meromictic lake. 30 p.
1962. Ph.D. Transport of radioisotopes in lakes. 152 p.
*Lind, Christopher T.
1967. Ph.D. The phytosociology of submerged aquatic macrophytes in eutrophic lakes of southeastern Minnesota. 118 p.
*Loeffler, Robert J.
1954. Ph.D. A new method of evaluating the distribution of planktonic algae in freshwater lakes. 205 p.
Lovshin, Leonard L.
1966. M.S. The relation of water temperature to growth of wild brook trout *(Salvelinus fontinalis)* in Lawrence Creek, Wisconsin. 48 p.
*Lueschow, Lloyd A.
1964. M.S. The effects of arsenic trioxide used in aquatic weed control operations on selected aspects of the bioenvironment. 66 p.
Lutz, Paul D.
1958. M.S. A study of general behavior in fishes, with emphasis on the homing pattern. 18 p.
*McNabb, Clarence D.
1956. M.S. No thesis.
1960. Ph.D. Part I. A method for enumerating freshwater phytoplankton concentrated on the membrane filter. Part II. A study of the phytoplankton and photosynthesis in sewage oxidation ponds in Wisconsin. 128 p.
McNaught, Donald C.
1965. Ph.D. A study of some ecological relationships and the role of vision in the diel migrations of *Daphnia*. 169 p.
McNaught, Mary E.
1964. M.S. No thesis.

Malueg, Kenneth W.
1966. Ph.D. An ecological study of *Chaoborus*. 231 p.
Miller, John A.
1958. M.S. A review of investigations, conducted at Wisconsin, on the olfactory mechanism of fishes and olfactory discrimination, by the bluntnose minnow *(Hyborhynchus notatus)*, of water from different marine water masses. 18 p.
Mueller, Warren M.
1975. M.S. Growth responses of sagittal otoliths to selected environmental variables. 16 p.
Mullen, Robert E.
1969. M.S. An investigation of the diel swimming activity of *Hyalella azteca* (Saussure) in Lake Mendota, Wisconsin. 49 p.
Nataraj, Jasharee.
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Neess, John C.
1949. Ph.D. A contribution to aquatic population dynamics. 103 p.
Nelson, Edward M.
1947. Ph.D. The comparative morphology of the Weberian apparatus in the family Catostomidae. 38 p.
Nursall, John R.
1953. Ph.D. The functional significance and evolution of the myomere pattern of fish-like chordates. 85 p.
Ogawa, Hisako.
1947. Ph.D. Studies on the origin, development and seasonal variations in the blood cells of the perch, *Perca flavescens*. 149 p.
Olsen, Eric K.
1971. M.S. Vertical and horizontal distribution of the pelagic fry of the walleye, *Stizostedion vitreum* (Mitchell), and yellow perch, *Perca flavescens* (Mitchell). 61 p.
1977. Ph.D. Distribution of pelagic yellow perch and walleye fry in two northern Wisconsin lakes. 86 p.
*Pampel, Leonard F.
1959. M.S. No thesis.
Parker, Michael.
1963. M.S. Preliminary observations on vitamin B12 in Lake Mendota. 34 p.
1966. Ph.D. Studies on the distribution of cobalt in lakes. 74 p.
Parker, Richard A.
1956. Ph.D. A contribution to the population dynamics and homing behavior of northern Wisconsin lake fishes. 86 p.
Peterka, John.
1960. M.S. Consideration of some problems in estimating trout populations in small lakes. 34 p.
*Ragotzkie, Robert A.
1953. Ph.D. The distribution of *Daphnia* in Lake Mendota and their mode of feeding. 98 p.
Robinson, John P.
1973. M.S. Migratory movements of adult coho salmon *(Oncorhynchus kisutch)* in Lake Michigan as revealed by ultrasonic telemetry methods. 91 p.
Sager, Paul E.
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1967. Ph.D. Species diversity and community structure in lacustrine phytoplankton. 201 p.
Salli, Arne J.
1962. M.S. A study of the age and growth of the rainbow trout (*Salmo gairdneri* Richardson) of the Brule River, Douglas County, Wisconsin, prior to migration to Lake Superior. 79 p.

1974. Ph.D. The distribution and behavior of young-of-the-year trout in the Brule River of northwestern Wisconsin. 278 p.

Schmitz, William R.

1953. M.S. Observations of the northern pike in Lake Mendota 1952. 38 p.

1958. Ph.D. Artificially induced circulation in thermally stratified lakes. 96 p.

Scholz, Alan T.

1977. M.S. No thesis.

Schwassmann, Horst O.

1962. Ph.D. Experiments on sun orientation in some freshwater fish. 153. p.

Siewert, Horst F.

1973. Ph.D. Thermal effects on biological production in a pond. 173 p.

Snow, Howard.

1972. M.S. No thesis.

*Sparr, M. C.

1958. M.S. The effect of chemical and physical treatments upon light penetration and phosphorus content of bog waters. 69 p.

1960. Ph.D. I. Quantitative chemical analysis of lake water using ion exchange resins. II. Investigation of the nutrient status of bog lakes using the growth of *Chlorella pyrenoidosa* as an index. 132 p.

Stewart, Kenton M.

1965. Ph.D. Physical limnology of some Madison lakes. 167 p.

Stone, Roderick C.

1961. M.S. Preliminary investigations of winter activity and movements of the yellow perch, *Perca flavescens* (Mitchell), in Lake Mendota, Wisconsin. 78 p.

Stross, Raymond G.

1958. Ph.D. Experimentally induced changes in lakes. a) Environmental changes following lime application to stained lakes. b) Changes in the planktonic crustacea following the introduction of trout to a fish-free lake. 125 p.

Teraguchi, Mitsuo.

1969. Ph.D. Diel vertical migration of *Mysis relicta* (Loven) in Green Lake, Wisconsin. 229 p.

Tibbles, J. J.

1956. Ph.D. A study of the movements and depth distribution of pelagic fishes in Lake Mendota. 193 p.

Voightlander, Clyde W.

1971. Ph.D. A study of growth rates of white bass, *Morone chrysops* (Rafinesque), with special reference to the utilization of the von Bertalanffy growth model. 206 p.

Walker, Theodore J.

1947. Ph.D. Olfactory discrimination of aquatic plants by *Hyborhynchus notatus* (Raf.). 86 p.

*Walton, Craig P.

1971. Ph.D. A biological evaluation of the molybdenum blue method for orthophosphate analysis. 218 p.

White, David A.

1967. Ph.D. Trophic dynamics of a wild brook trout stream. 183 p.

White, Ray J.

1964. M.S. Progress report on a study of the wild brown trout population and its habitat in Black Earth Creek, Wisconsin. 109 p.

1972. Ph.D. Responses of trout populations to habitat change in Big Roche-a-Cri Creek, Wisconsin. 296 p.

Williamson, John L.

1965. M.S. The artificial stocking of walleye fry to augment native year class strength in Little John and Erikson Lakes, Vilas County, Wisconsin. 16 p.

*Winter, Donald R.
1970. M.S. Water quality and trophic condition of Lake Superior (Wisconsin waters). 69 p.
Wisby, Warren J.
1952. Ph.D. Olfactory responses of fishes as related to parent stream behavior. 42 p.
Wissing, Thomas E.
1969. Ph.D. Energy transformations, food habits and growth rates of young-of-the-year white bass, *Morone chrysops,* in Lake Mendota, Wisconsin. 147 p.
Wright, Thomas D.
1964. M.S. Aspects of the early life history of the white bass, *Roccus chrysops.* 38 p.
1968. Ph.D. An electrophoretic analysis of the effects of isolation, homing behavior, and other factors on the serum proteins of the white bass *(Morone chrysops)* in some Wisconsin lakes. 75 p.
Yokoyama, Misako O.
1947. Ph.D. Studies on the origin, development and seasonal variations on the blood cells of the perch, *Perca flavescens.* 150 p.
*Zicker, Eldon.
1955. Ph.D. The release of phosphorus from bottom muds and light penetration in northern Wisconsin bog lake waters as influenced by various chemicals. 89 p.

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