SPECIES ABUNDANCE RELATIONSHIPS OF AQUATIC INSECTS IN MONOTYPIC WATERHYACINTH COMMUNITIES IN FLORIDA, WITH SPECIAL EMPHASIS ON FACTORS AFFECTING DIVERSITY

By

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Dedicated to my father, Jurgis,
whose support made this possible.

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Collections of aquatic insects beneath monotypic waterhyacinth communities, initially standardized by collecting effort, later based on a standard sampling area, were made at 37 different sites in 18 Florida counties. Identifications, verified by authorities for respective groups of the 5485 specimens collected, indicated 147 species of aquatic insects were present. Comparison of this species list with those from 2 other studies more limited in scope indicated several misidentifications by previous workers and a much greater range of aquatic entomofauna. Although the low level or absence of dissolved oxygen (DO) has been frequently reported, DO-breathing forms were abundant and frequent in my collections.

The importance of the relative abundances of each species at the collection sites was demonstrated by discriminant analysis which showed that the 3 repetitively sampled sites were significantly different based on the abundances of only the 10 most frequently collected insects. Species abundances were also used in 2 methods of estimating the total number of species present at each of the 3 study sites. Statistical fitting of an exponential species accumulation curve revealed that approximately all species present at each site had been collected. The fitting of a lognormal distribution curve to the plot of the species abundance data indicated that approximately 70% of the total species present at each site had been collected.

Reducing the species abundance distribution for each collection to a single statistic often helps in elucidating the effects of plant morphometric, water quality and other parameters. Diversity indices, especially those which combine species richness and species evenness, are the most common method of reducing the species distribution data to one statistic, and 3 different diversity indices were calculated for all my collections. All 3 indices indicated an increase in diversity with decreasing values of alkalinity or some parameters strongly correlated with it. Higher levels of iron in the water increased the diversity at least for the Camps Canal study site. However, none of the diversity indices were able to distinguish between the 3 study sites, indicating a loss of information due to the reduction to a single statistic. The use of diversity indices would thus appear to have more limitations than might be inferred from their popularity in ecological literature.

INTRODUCTION

Although waterhyacinths cover an estimated 200,000 acres of water in Florida, the aquatic entomofauna beneath them has scarcely been studied. Some researchers believe that the water beneath waterhyacinth mats is relatively devoid of life due to a reduction of dissolved oxygen. Of the two previous studies of aquatic insects beneath waterhyacinths, one was restricted to canals in South Florida, the other to a single reservoir in Central Florida; neither identified the aquatic insects to species level. By collecting and identifying aquatic insects beneath waterhyacinth communities at 37 locations in 18 Florida counties, I hoped to provide a better picture of the variety and extent of the aquatic life in this common Florida habitat.

Many studies of a particular habitat are surveys, reporting only the presence of a species. By standardizing my collecting methods, I hoped to determine if the abundance of individuals in each species was also important. By taking measurements of the waterhyacinths and a number of water quality parameters, I hoped to elucidate the environmental factors affecting species composition and abundance. Repetitive sampling of 3 study sites also would allow detection of seasonal changes in the composition of the aquatic entomofauna and determination of whether the abundances of different species could be used to differentiate between the sites.

The utility of species abundances for determining the estimated number of species present at a sampling site was demonstrated by 2 different methods. By comparing the results of the estimated total number of species, as calculated by fitting an exponential species accumulation curve, with the estimate obtained by fitting a lognormal distribution curve to the species abundance plot, I gained a knowledge of these techniques and their relative value.

Several diversity indices which reduce the number of species and their relative distributions to a single statistic were calculated. Their utility in describing a collection could then be tested, as could the effects of environmental factors on these indices.

The use of various multivariate statistical techniques and numerical ecological methods not only illustrated their utility for ecological research but also helped define the important parameters and their interactions in these water-hyacinth communities and the methods which could be used to detect them.

LITERATURE REVIEW

Eichhornia crassipes (Martius) Solms-Laubach

Description

The waterhyacinth, Eichhornia crassipes, is a widespread aquatic weed. The most recent botanical treatment of this species is probably by Agostini (1974, p. 305), whose description of the species, as translated by Center (1976, p. 5), is:

> Plants floating or sometimes fixed to the substrate, the leaves in the form of a rosette with the stem reduced and the plants connected by an elongated horizontal rhizome; numerous plumose roots issue from each plant. The aerial leaves are variable in shape; petioles of 2 to 30 cm long are more or less inflated; stipules 2-15 cm long with a small apical orbicular-reniform lamina with a lacerate [serrate?] margin; submerged leaves never evident. Inflorescence variable, internodes between the spathes nearly absent; inferior spathe with lamina 1-5 cm long, the sheath 3.5-7 cm long. Flower 4-6 cm long; perianth light purple or rarely white, tube 1.5-2.0 cm long, lobes 2.5-4.5 cm long, with entire margins. Stamens all exserted, filaments villous-gladular. Capsule elliptical, trigonous, 12-15 mm long; seeds oblong-elliptical 1.2-1.5 x 0.6-0.6 mm with 10 longitudinal ridges.

Taxonomy

Eichhornia is one of 9 genera, all aquatic, of the pickerelweed family, Pontederiaceae, all but 2 of which are considered endemic to the New World (Cook *et al*. 1974). The waterhyacinth is the most widespread of the 7 species of this mainly neotropical genus. E. crassipes is the only member of the genus found in the United States, although there are reports of E. azurea (Sw.) Kunth in South Florida (Burkhalter 1974).

Waterhyacinth first received the attention of European taxonomists during the beginning of the nineteenth century, and Bock (1966) has an excellent historical review of the taxonomy of this species. Center (1976, p. 3) cites Agostini (1974) for the following synonomy for Eichhornia crassipes:

> Eichhornia crassipes (Mart.) Solms in DC., Monogr. Phan. 4:527. 1883.
>
> > Pontederia crassipes Mart., Nov. Gen. 1:9. t. 4. 1824.
> >
> > Piaropus crassipes (Mart.) Raf., Fl. Tell. 2: 81. 1837.
> >
> > Eichhornia speciosa Kunth, Enum. Pl. 4: 131. 1843.
> >
> > Eichhornia cordifolia Gandog., Bull. Soc. Bot. France 66:294. 1920.

The scientific synonyms E. speciosa and Piaropus crassipes are especially common in the literature even 50 years after Solms-Laubach's revision.

While the binomial Eichhornia crassipes has gained widespread acceptance in the last 30 or 40 years, the authorship of the name is often confused, sometimes being mistakenly attributed to Kunth. The correct form for the scientific name with the authors abbreviated is "Eichhornia crassipes (Mart.) Solms".

E. crassipes has a variety of common names in different parts of the world, with Bock (1966) listing 48 names from

18 countries. In the English language the name waterhyacinth is commonly used. The structure of the name varies, however, sometimes being written as one word (waterhyacinth), as a hyphenated word (water-hyacinth), or most frequently as two words (water hyacinth). Although most modern authoritative botanical works (_e_._g_. Cook _et_ _al_. 1974, Muenscher 1967, Stodola 1967) use the two-word form "water hyacinth," I will use the single-word form "waterhyacinth," as recommended in Kelsey and Dayton's (1942) list of standardized plant names and in the Composite List of Weeds by the Subcommittee on Standardization of Common and Botanical Names of Weeds (Anonymous 1966).

Distribution--Florida

Waterhyacinth, now generally believed to be a native of South America, is widely distributed throughout the tropical, subtropical and, occasionally, temperate regions of the world (Holm _et_ _al_. 1969, Bock 1966, Center 1976). Although some earlier workers consider waterhyacinth a native of Florida (Buckman 1930, Small 1933, Muenscher 1967), most agree that it was introduced. Goin (1943) cites a University of Florida botany professor with crediting the U. S. introduction of waterhyacinth to the Venezuelan delegation to the 1835 Centennial Exposition, with waterhyacinth subsequently being introduced about 1840 into Florida by cattle-growers. There is an amazing reference (Gowanloch 1944) that waterhyacinth was introduced to South America from Japan. This report is probably due more to wartime emotionalism than scientific fact. Penfound and Earle (1948) mention that it may have been cultivated as a greenhouse plant as early as shortly after the Civil War. As Bock (1966) points out, it is difficult to believe that a species as large and showy as waterhyacinth was overlooked until the late 1880's by all the early botanists in the state. Most authorities agree that, directly or indirectly, the waterhyacinths in Florida came from those brought from Venezuela by the Japanese delegation for distribution as souvenirs at the 1884 International Cotton Exhibition (sometimes referred to as the 1884 Cotton Centennial Exhibition) in New Orleans (Klorer 1909, Buckman 1930, Penfound and Earle 1948, Tabita and Woods 1962).

Although the precise time and area where waterhyacinths were introduced into Florida is not surely known, the earliest reports place it in the St. Johns River near Palatka in 1890. A New York newspaper account (Anonymous 1896) quotes a Mr. J. E. Lucas of Palatka that the waterhyacinths were introduced by a Mr. Fuller [in 1891] into the St. Johns River seven miles north of Palatka at Edgewater Grove from plants brought originally from Europe. Webber (1897) places the point of introduction ". . . about 1890, at Edgewater, about four miles north of Palatka" (p.11), while Tilghman (1962), an old resident of Palatka, states "Florida's first water hyacinth was placed in the St. Johns River by a winter visitor, Mrs. W. F. Fuller, at San Mateo, five miles south of Palatka" (p. 8). Most subsequent workers (Buckman 1930, Penfound and Earle 1948, Tabita and Woods 1962, Seabrook 1962, Zeiger 1962, Raynes 1964, and many others) give similar versions of the introduction based directly or indirectly on the above accounts.

In 1897 waterhyacinth distribution in Florida was thought to be confined to the St. Johns River and its tributaries and a few landlocked lakes (Webber 1897). In 1930 waterhyacinths seemed still to be confined to the 42-square-mile (26,800 acres) St. Johns River drainage (Buckman 1930). By 1947 the estimated area of infestation increased to 63,000 acres and to approximately 80,000 acres by 1962 (Tabita and Woods 1962). In 1964 an estimated 90,000 acres were infested (Ingersoll 1964), while by 1972 the estimated area of infestation had increased to 200,000 acres (Perkins 1973). The 1975 estimate is also 200,000 acres (Center 1976).

Productivity and Reproduction

This increase in the area infested, despite massive control measures dating back over 75 years, points out the remarkable reproductive ability of this plant. Considered one of the world's most productive photosynthetic organisms (Westlake 1963), waterhyacinths under optimal conditions may double in number in 11 to 18 days (Penfound and Earle 1948). Center (1976) presents a table on waterhyacinth productivity and standing crop compiled from many different sources.

Such rapid increase in new plants is due primarily to vegetative reproduction (Hitchcock *et al*. 1950), with one plant producing many offsets, or suckers, on stolons (Penfound and Earle 1948). New plants are also regenerated from broken portions of the rhizome (*ibid.*).

Unlike California and some other parts of the world (Bock 1966), in Florida reproduction from seed definitely occurs, with about 5% germinating under normal conditions (Zeiger 1962). Seeds are considered important in Florida chiefly as propagules for infesting new areas or for reinfesting areas where waterhyacinths had been controlled.

Environmental Requirements

Although it is frequently believed that the absence of waterhyacinths in a suitable body of water is due to the lack of introduction of a propagule (Penfound and Earle 1948), this is probably an over-simplification. As Morris (1974) points out, an invading organism's success is due not only to favorable physical factors such as nutrients, light and temperature, but also to the competitive ability of plants already present in the area. He demonstrated that waterhyacinths would not become established when introduced to an area with abundant native vegetation. However, man frequently alters these natural, balanced, aquatic systems, sometimes by increasing the nutrient level. A good colonizing species like waterhyacinth can easily become established and outcompete the native flora in such disturbed aquatic systems.

Light. Waterhyacinths require reasonably high light intensities for growth, at least 60% full sunlight according to Bock (1966). Penfound and Earle (1948) found that the light intensity in July above a waterhyacinth mat was 420 footcandles and noted that plants at 130 footcandles were dying. Knipling et al. (1970) found that photosynthesis increased from 7.8 mg CO_2/dm^2 leaf surface/hr to 16.1 mg/dm^2/hr when light intensity increased from 1450 to 8000 footcandles.

Air temperature. Waterhyacinths can easily survive freezing temperatures for short periods of times. Webber (1897), Buck (1930) and many subsequent workers observed regrowth of shoots from the submerged rhizome after the tops of the plants had been killed by frost. Survival at 21°F for 12 hrs has been recorded, with lower temperatures killing the rhizome and preventing regrowth (Penfound and Earle 1948). I could find no literature on optimum or maximum air temperatures for waterhyacinth; however, it is undoubtedly fairly high, as most prolific growth usually occurs during summer when daytime temperatures are frequently in the upper 80's and low 90's °F. Balciunas (unpublished data) observed luxuriant growth in a greenhouse where daytime summer temperature was consistently about 100°F.

Water temperature. Knipling et al. (1970) determined that the optimum water temperature for waterhyacinth was 28-30°C (82.4-86.0°F) but that growth was relatively high over the range of 22-35°C (71.6-95.0°F). Waterhyacinths will survive a water temperature of 34°C (93.2°F) for 4 or 5 weeks (Penfound and Earle 1948), but higher temperatures are detrimental, with negative growth occurring at 40°C (104°F).

Water depth. Waterhyacinths can grow on land; Penfound and Earle (1948) noted survival of plants for up to 18 days out of water. A high soil moisture content seems necessary for prolonged survival (Webber 1897, Bock 1966).

There seems to be no good correlation between increasing water depth and waterhyacinth growth (Morris 1974).

Water Quality

Hydrogen ion concentration. Waterhyacinth seems tolerant to pH values normally encountered in aquatic systems. Haller and Sutton (1973) found that optimal growth occurred in acid to slightly alkaline conditions (pH 4-8) and some growth occurred from pH 8.0 to 10.0. Bock (1966), citing various sources, gives a pH range of 4 to 9. Penfound and Earle (1948) found that the pH of water beneath waterhyacinths usually ranged from 6.2-6.8 but that waterhyacinths could tolerate extremes of 4-5 and 9-10. Chadwick and Obeid (1966), in comparing growth of waterhyacinths and waterlettuce (*Pistia stratiotes* L.), found that optimal growth for waterhyacinths occurred at a pH of 7.0 while 4.0 was optimal for waterlettuce. Center and Balciunas (1975), comparing water quality at various locations having waterhyacinths, alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.), or neither weed, found there was little difference in the pH preferences of the plants and that the pH of areas with waterhyacinth was slightly lower (7.06 ± 0.84), though not significantly, than the pH of areas having no aquatic weeds (7.55 ± 1.06).

Nutrients. Dymond (1948) and Hitchcock et al. (1949) found that waterhyacinths grow well in nutrient-poor as well as in nutrient-rich water but that added nutrients favor growth. Haller et al. (1970) found that less than 0.01 ppm phosphorus was limiting to waterhyacinth growth and that above this level phosphorus was absorbed in luxury amounts. Haller and Sutton (1973) found that maximum growth occurred in water with a phosphorus concentration of 20 ppm and that levels greater than 40 ppm were toxic. Boyd and Scarsbrook (1975) added fertilizer at 4 different levels to waterhyacinth ponds and found that the lowest waterhyacinth biomass yield was from unfertilized ponds while the highest yields came from ponds with the intermediate level of fertilization.

Wahlquist (1972) compared yields of waterhyacinths grown with no fertilizer, with fertilizer containing phosphorus, and with fertilizer containing both nitrogen and phosphorus. He found that fertilized ponds had much higher yields (550.4 and 590.9 metric tons/ha) than unfertilized ponds (174.5 metric tons/ha) and that ponds fertilized with nitrogen and phosphorus had a slightly higher (but statistically insignificant) yield than ponds fertilized with phosphorus only.

Salinity. Although plants can survive up to 13 days in 100% seawater (Bock 1966), waterhyacinth is intolerant to salt water, with Buckman (1930) listing a survival time of only 24 hrs. Penfound and Earle (1948) found that waterhyacinths did not tolerate more than slightly brackish water and were not found in lakes or streams with an average salinity greater than 15% seawater.

Alkalinity. Center and Balciunas (1975) found the alkalinity of water containing waterhyacinths or alligatorweed was higher than that of water without either species.

Metallic ions. Sutton and Blackburn (1971a, 1971b) found that 3.5 ppm copper for 2 weeks inhibited waterhyacinth growth.

Center and Balciunas (1975) found waterhyacinths more tolerant of low iron levels than alligatorweed. Morris (1974) found no correlation between waterhyacinth growth and the levels of copper and iron at his study sites.

Economic Importance

Problems. The explosive growth of waterhyacinth has caused it to be ranked as one of the 10 most important weeds and *the* most important aquatic weed (Holm *et al.* 1969). The massive amount of literature on the problems caused by waterhyacinth is well reviewed by Del Fosse (1975) and Center (1976). A list of the main categories of problems is:

(1) Interference with navigation;

(2) Clogging of water drains, irrigation canals, spray equipment and pumps;

(3) Interference with fishing, swimming and other aquatic recreational activities;

(4) Oxygen depletion caused by heavy infestations, making water inhospitable to many aquatic organisms;

(5) Increased evapotranspiration rates in an infested area (1.5 to 5 times higher than evapotranspiration from adjacent open water);

(6) Reduction of fish populations by destruction of spawning beds, competition for nutrients and space, depletion of dissolved oxygen, and by preventing predators from finding small organisms;

(7) Creation of deep beds of organic sediment;

(8) Reduction of open water available to waterfowl;

(9) Creation of ideal breeding places for certain mosquitoes, some of them disease vectors;

(10) Increased flooding due to obstruction of waterways;

(11) Occasional destruction of bridges, trestles and other structures during flooding;

(12) Shading out and otherwise out-competing beneficial aquatic vegetation;

(13) Monetary and ecological costs of control;

(14) Rendering unsightly and aesthetically unpleasant the water surfaces which they completely cover.

Control. The U. S. Army Corps of Engineers estimates that a total of $76 million was allocated for aquatic weed control in Florida during fiscal year 1976, with almost $5 million being allocated for waterhyacinth control (Center 1976). Morris (1974) cites a USDA source for a $12-$16 million estimate of the costs of waterhyacinth control in Florida in 1973.

The literature on waterhyacinth control is enormous. There is even a Hyacinth Control Journal (renamed in 1975 the Aquatic Weed Management Journal) which began publication in 1962. Pieterse (1974) provides a good review of the most important literature on waterhyacinth control. Del Fosse (1975) has a more detailed review of the various aspects of waterhyacinth control.

There are also good, recent review articles for each particular aspect of waterhyacinth control: methods of mechanical control have been reviewed by Robson (1974); chemical control and the various compounds available were reviewed by Blackburn (1974); biological control of aquatic weeds has been reviewed by Bennett (1974) and by Andres and Bennett (1975). The use of plant pathogens was reviewed by Zettler and Freeman (1972), Freeman *et al*. (1974) and by Charudattan (1975). Mitchell (1974) reviewed habitat management as a means of aquatic weed control.

Utilization. Possible beneficial uses of waterhyacinths have been a concern of even the earliest reports (Webber 1897, Buckman 1930, Penfound and Earle 1948). Bock (1966), Pieterse (1974), Del Fosse (1975), and Center (1976) all review the abundant literature regarding the beneficial aspects of waterhyacinths, the main ones of which are:

(1) Removal of nutrients from water, including use of waterhyacinths in sewage treatment;

(2) Protection of shorelines from erosion;

(3) Use as mulch and fertilizer;

(4) Use as a source of production of natural gas;

(5) Increase in aquatic organisms utilizable as fish food;

(6) Use as fodder for cattle, pigs, catfish or other animals;

(7) Shading out of nuisance submerged plants like *Hydrilla*;

(8) Decrease in breeding habitat for certain mosquito species (Barber and Hayne 1925);

(9) Use in construction of a large variety of objects, *e.g.*, chair bottoms, cigar wrappers, ice chests, paper;

(10) Aesthetic appeal of beautiful blossoms and luxuriant green foliage.

Habitat for Aquatic Insects

The insects found beneath waterhyacinths have received little attention. Most of the literature about insects associated with waterhyacinths deals with those which might have potential as control agents through their feeding activity or transmission of pathogens. Fred Bennett of the Commonwealth Institute for Biological Control in Trinidad has published many papers on insects and mites on waterhyacinth and their possible use as biocontrol agents (Bennett 1967, 1968a, 1968b, 1970, 1972, Bennett and Zwolfer 1968). Others who have provided lists of insects attacking waterhyacinth are Gordon and Coulson (1969), Coulson (1971), Perkins (1972, 1974), and Spencer (1973, 1974). None of these investigators mentions any aquatic insects except the weevils, *Neochetina* spp., which build their pupal case in the root hairs of waterhyacinths (DeLoach 1975).

Waterhyacinths' extensive root systems, sometimes over a meter in length, create a vast new habitat for a variety of aquatic insects where previously a few larger, predaceous, open-water forms dominated. Weber (1950) estimates the area of the roots of one small waterhyacinth is 7.31 square meters. O'Hara (1968) believes that waterhyacinth has a greater interface area than any other aquatic plant.

Although Goin (1943) thought that the root length of waterhyacinth plants was dependent on the depth of the water beneath them, it has been demonstrated that root length is a function of the nutrient content of the water: the longest roots occur in nutrient-poor waters, the shortest roots in nutrient-rich water (Wakefield and Beck 1962, Haller and Sutton 1973, Morris 1974). The blue color frequently seen in the roots, often cited as a diagnostic aid, is also due to water quality. Plants grown in phosphorus-deficient water have iridescent blue roots, indicative of anthocyanin production and phosphorus deficiency, while roots of plants grown in nutritive waters are a normal, gray-black color (Haller and Sutton 1973).

While fishermen (Tilghman 1962) frequently praise the waterhyacinth for producing an abundance of aquatic insects and other organisms desirable as fish food, most investigators disagree. They believe the apparent abundance of aquatic organisms occurs only on the edge of a mat, with the water under the center of the mat being ". . . unsuitable for the existence of most forms of plankton and aquatic insect life." (Lynch *et al*. 1947, p. 64). Many agree, citing low levels of dissolved oxygen beneath a solid mat (Lynch 1947, Ultsch 1971, 1973). Wahlquist (1969) believes the reduction of fish yield in waterhyacinth-infested ponds is due to shading out of phytoplankton by waterhyacinths.

Few workers have actually surveyed the aquatic entomofauna of waterhyacinths. Goin (1943) surveyed the lower vertebrate forms of waterhyacinth communities but he mentions only one insect, the midge *Chironomus*. O'Hara (1961, 1968) surveyed the invertebrate fauna of waterhyacinth-covered canals in South Florida and lists the insects collected, most of which are identified only to family. Katz (1967), in her study of the effects of chemical eradication of waterhyacinths on the associated aquatic fauna, provides lists of insects on and below waterhyacinths. Most of the insects are identified to the generic level, but I suspect there are many erroneous identifications. Hansen *et al*. (1971), in studying the food chains of aquatic organisms beneath waterhyacinths, mentions several different aquatic insects. Lynch *et al*. (1947) collected a relatively small number of aquatic insects from beneath waterhyacinths, most of which were identified to family or order. Wahlquist (1969) also mentions some insects, identified only to family or order, which serve as food for fishes living in waterhyacinth-covered ponds.

The only group of aquatic insects whose relationship to waterhyacinth has been investigated more thoroughly is the mosquitoes (Culicidae). Barber and Hayne (1925) list 4 species of *Anopheles* collected among waterhyacinths, *A. crucians* being the most common. Seabrook (1962), in his study of correlation of mosquito breeding to waterhyacinths, mentions 2 species of *Anopheles* and all 3 species of *Mansonia* as being associated with waterhyacinths. He, along with Barber and Hayne (1925) and Lynch *et al*. (1947), believes that waterhyacinths increase mosquito production. However, Viosca (1924; cited by Barber and Hayne 1925), Mulrennan (1962) and Ferguson (1968) believe that waterhyacinths reduce mosquito production by shading out planktonic food and the submerged plants which serve as refuges.

The only other references I found to aquatic insects associated with waterhyacinths are casual references by entomologists to the habitat where a certain species was collected, *e.g.*, Blatchley (1914, 1925), Young (1954).

METHODS

Aquatic insects were collected 88 times in 37 different waterhyacinth communities in 18 Florida counties. In addition, 3 study sites in Alachua County (Camps Canal, Lake Alice, and a drainage ditch at Interstate 75) were sampled repeatedly in order to ascertain seasonal and other temporal changes. Twenty-nine collections were made at Camps Canal, including regular samples at 2- to 3-week intervals during all of 1974. The first collection was made 12 Aug. 1972, the last on 5 Dec. 1974. Table 1 presents a list of collection sites and dates.

Sample Site Selection

The exact sampling point at a given collection site was selected on the basis of several considerations. An area containing an essentially pure stand of waterhyacinths was chosen in order to eliminate complicating effects which other aquatic or successional plants might have on the biota beneath a waterhyacinth mat. The waterhyacinth communities sampled were essentially monotypic, although almost all contained small amounts of duckweed, *Lemna* and *Spirodella* spp., and/or some water fern, *Salvinia* and *Azolla* spp. Watermeal, *Wolfia* spp. and *Wolfiella* spp., was sometimes present mixed with the *Lemna*. These floating macrophytes were seldom

Table 1. List of collection sites.

COLLEC_NO	SITE	LOCATION	DATE
1	ARTIFICIAL POOL	USDA LABORATORY, GAINESVILLE, FLA.	12 AUG '72
2	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	13 AUG '72
3	CAMP'S CANAL	BY RT. 234 BRIDGE, ALACHUA CO., FLA.	14 AUG '72
4	UNNAMED CANAL	BY E. EDGE OF LAKE HARRIS, LAKE CO., FLA.	22 SEP '72
5	DITCH-CANAL	AT SW [illegible] ST & 7[illegible] AV., FT. LAUDERDALE, FLA.	22 SEP '72
6	ROADSIDE CANAL	ALONG FLA. TPK., INDIAN RIVER CO., FLA.	22 SEP '72
7	ROADSIDE CANAL	ALONG FLA. TPK., [illegible] CO., FLA.	22 SEP '72
11	UNNAMED POND	[illegible] G'VILLE COUNTRY CLUB, ALACHUA CO. FLA	[illegible] JUN '73
12	[illegible] POND	ROCKY POINT [illegible], GAINESVILLE, FLA.	24 JUN '73
13	[illegible]	BY S. MAIN ST GAINESVILLE, FLA.	25 JUN '73
14	UNNAMED MARSHY LK.	OFF OF US RT 441 S OF GAINESVILLE, FLA.	30 JUN '73
15	UNNAMED MARSHY LK.	OFF OF WILLISTON RD W OF I-75, ALACHUA CO., F	1 JUL '73
16	UNNAMED MARSHY LK.	OFF OF WILLISTON RD W OF I-75, ALACHUA CO., F	1 JUL '73
17	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	2 JUL '73
18	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	2 JUL '73
19	UNNAMED LAKE-MARSH	INTERSEC. NW MAIN & 13 STS., GAINESVILLE, FLA	3 JUL '73
20	OTTER CREEK	BY U. S. RT. 19 BRIDGE, LEVY CO., FLA.	6 JUL '73
21	OTTER CREEK	BY US. RT. 19 BRIDGE, LEVY CO., FLA.	6 JUL '73
22	DRAINAGE DITCH	BY I-75, 3 MI. N. OF MICANOPY, FLA.	10 JUL '73
23	ROADSIDE CANAL	CROSSING PAYNE'S PRAIRIE ALONG I-75, ALACH CO	11 JUL '73
24	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	11 JUL '73
25	SWAMP	BY ST. RT. 2[illegible] N. OF RIVER STYX, ALACHUA CO.	13 JUL '73
26	LAKE LAWNE	[illegible] I. N RT. [illegible] EAST OF ORLANDO, ORANGE CO.	17 JUL '73
27	SMALL STREAM	SR 2[illegible] 2.5 MI N S-32[illegible], ALACHUA CO.	16 JUL '73
29	RIVER STYX	BY ST. RT. 3[illegible] BRIDGE, ALACHUA CO., FLA.	19 JUL '73
30	KANAPAHA LAKE	SW GAINESVILLE, FLA.	12 SEP '73
31	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	13 SEP '73
32	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	19 SEP '73
33	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	20 SEP '73
34	ROADSIDE DITCH	BY ST RT 324 S OF US RT [illegible], ALACHUA CO., FLA	2 OCT '73
35	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	19 OCT '73
36	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	19 OCT '73
37	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	23 OCT '73
38	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	19 NOV '73
39	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	19 NOV '73
40	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	21 NOV '73
41	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	12 DEC '73
42	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	12 DEC '73
43	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	12 DEC '73
44	CULVERT	LEADING INTO LK HARRIS UNDER RT 27, LAKE CO.	13 DEC '73
45	SWAMPY STREAM	KIRBY STORTER PARK OF US RT 41, COLLIER CO.	15 DEC '73
46	ROADSIDE CANAL	ALONG RT 441, PALM BEACH CO., FLA.	18 DEC '73
47	SMALL STREAM	CROSSING US RT 441 N OF PAHOKEE, MARTIN CO.	18 DEC '73
48	SMALL STREAM	CROSSING US RT 441, OKEECHOBEE CO., FLA.	13 DEC '73
49	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	15 JAN '74
50	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	15 JAN '74
51	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	16 JAN '74
52	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	4 FEB '74
53	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	6 FEB '74
54	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	6 FEB '74
55	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	15 FEB '74
56	CAMP'S CANAL	BY ST. RT. 234 BRIDGE, ALACHUA CO., FLA.	17 FEB '74
57	DRAINAGE DITCH	BY I-75 3 MI N OF MICANOPY EXIT, ALACHUA CO.	17 FEB '74
69	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	18 APR '74
70	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	1 MAY '74
71	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	2 MAY '74
72	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	15 MAY '74
73	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	20 MAY '74
74	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	13 JUN '74
75	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	19 JUN '74
76	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	26 JUN '74
77	SMALL STREAM	US RT 301 S DADE CITY 1 MI N RT 98, PASCO CO	29 JUN '74
78	SMALL POND	HARDEE CO. CAMPGROUNDS, HARDEE CO.	30 JUN '74
79	STREAM-CULVERT	US RT 17, .5 MI N RT 74, CHARLOTTE CO.	30 JUN '74
80	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	10 JUL '74
81	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	23 JUL '74
82	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	7 AUG '74
83	CULVERT	I-75 2.5 MI N MICANOPY, ALACHUA CO.	7 AUG '74
84	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	14 AUG '74
85	RIVER STYX	BY SR 3[illegible] BRIDGE, ALACHUA CO.	15 AUG '74
86	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	22 AUG '74
87	SMALL STREAM	SR 2[illegible] 2.5 MI N S-32[illegible], ALACHUA CO.	27 AUG '74
88	LAKE ALICE	UNIV. OF FLA., GAINESVILLE, ALACHUA CO.	27 AUG '74
89	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	28 AUG '74
90	DRAINAGE DITCH	I-75 3 MI N MICANOPY, ALACHUA CO.	29 AUG '74
91	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	11 SEP '74
92	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	26 SEP '74
93	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	10 OCT '74
94	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	24 OCT '74
95	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	7 NOV '74
96	LAKE TALQUIN	[illegible] BRIDGE, GA[illegible]	9 NOV '74
97	ROADSIDE DITCH	[illegible] MI N COUNTY LINE, LIBERTY CO.	11 NOV '74
98	WACISSA RIVER	SPRINGS AT [illegible], JEFFERSON CO.	11 NOV '74
99	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	21 NOV '74
100	LAKE GLENADA	PARK 1 MI S AVON PARK, HIGHLANDS CO.	29 NOV '74
101	CAMP'S CANAL	BY SR 234 BRIDGE, ALACHUA CO.	5 DEC '74
102	PEACE RIVER	HARDEE CO. CAMPGROUNDS, HARDEE CO.	17 DEC '74
103	[illegible] CREEK	1[illegible] MI S ARCADIA ON RT [illegible], DE SOTO CO.	17 DEC '74

abundant except in a few places where waterhyacinth growth was poor and the waterhyacinth plants widely separated from each other. Emergent, rooted aquatic vegetation such as cattails, *Typhus* sp., and grasses was sometimes present along the shoreline, but submerged aquatic plants were almost never present beneath the waterhyacinth mat, although they were sometimes within the sampling area.

Within a mat a sampling point which was some distance (2-20 meters) from the shoreline was usually chosen in order to eliminate ecotone and emergent vegetation effects. The sampling point was reached by wading if water depth and bottom configuration permitted; otherwise, 2 Styrofoam billets allowed me to reach and sample the interior of the mat by alternately standing on one billet and moving the other.

Accessability was another consideration. Since a considerable amount of equipment, *e.g.* Hach test kit, Styrofoam billets, sampler, collecting and recording equipment, had to be transported, suitable sampling areas near roads were usually favored.

Collection Methods

The collections made in 1972 (#1 - #7) were strictly qualitative, with no attempt at standardization.

Standardized collection time. The 1973 collections, along with those from the early part of 1974 (#11 - #58), were made on a standard-time basis, *i.e.*, a waterhyacinth mat was sampled for approximately 1 hour, usually divided into 2 half-hour subsamples.

If the waterhyacinth mat was not too thick, a triangular dip net was placed well under the plants and a clump of waterhyacinths was lifted inside the net out of the water. The contents of the net and the waterhyacinths were washed in a pail of water, then small portions of water from the pail were poured into a white enamel pan and searched for insects, which were placed into a vial of 70% alcohol. Each vial had a collection number placed inside and also written on the stopper. Once all the water in the pail had been searched for insects, the entire procedure was repeated until the time period elapsed.

The entire contents of the pail were searched even if the time period ended before all the water had been examined. Actual time spent collecting the insects, as well as number of plants and petioles searched, their height above the water, root length and water depth were recorded. Offsets were considered plants if a root system had developed; petioles were counted only if they had a portion of a green leaf.

If a mat was too thick, *i.e.*, the numerous stolons and petioles prevented passage of the dip net, then a clump of waterhyacinths would be quickly pulled out of the water into the pail, the roots washed and the water examined as previously outlined. This standardized collection time method or "catch per unit effort" is a valid way of estimating insect population density (Morris 1960), however, preliminary analysis of my data showed that extension of these type data could lead to spurious conclusions.

Standardized area. A sampler which would cut through a waterhyacinth mat and capture the organisms underneath was designed and constructed. It consisted of a rectangular aluminum box, 80 x 40 x 50 cm, open at both ends, reinforced with an external frame and with strips of sharpened stainless steel attached to the bottom edge. The sampler, when brought down vigorously in a vertical position on top of a waterhyacinth mat, cut a 1/5-square-meter (0.2 m^2) section out of the mat. A 10-cm high aluminum drawer with a double mesh bottom was then quickly inserted into a slot 15 cm from the bottom of the sampler, thus enclosing the waterhyacinth mat sample and aquatic organisms beneath it in the sampler.

The sampler was then lifted out of the water, the water was drained through the screen drawer, and the drawer was searched for aquatic organisms, washed and searched again. Roots of waterhyacinths trapped inside the sampler were washed vigorously in a bucket of water and the water was searched for aquatic organisms. Although some active organisms might have eluded capture by swimming straight down before the drawer could be inserted in the sampler, the presence of numerous fish, crayfish and other active swimmers inside the sampler indicated that it was reasonably effective in capturing the organisms beneath the waterhyacinth mat. As with the standard-time sampling method, plant height, root length and water depth as well as number of plants and petioles inside the sampler were recorded. Water temperature at a depth of approximately 15 cm was also recorded.

Water Quality

Water quality data for each collection site were taken in the following manner. Three water samples were drawn from a depth of about 15 cm in pint-sized Whirl-pak^{R} plastic bags labelled with the collection number. Total alkalinity, total hardness, pH and specific conductance of one sample were tested immediately, using a portable Hach DR-EL/2 test kit. At the laboratory, the second sample was tested with the Hach kit for chlorides, total nitrates and nitrites, total phosphates, and sulphates. The third water sample was refrigerated until delivered to the University of Florida Soils Laboratory, which conducted a variety of tests, of which those for copper, potassium and iron were the most important.

The methods applied to the water samples were:

alkalinity (total)--titration;
chloride--titration, mercuric nitrate;
copper--atomic absorption spectrophotometer;
hardness (total)--titration, Titra Ver;
iron--atomic absorption spectrophotometer;
nitrates and nitrites (total)--cadmium reduction;
pH--calorimetric, wide-range;
phosphates--ascorbic acid, Phos Ver III;
potassium--flame emission spectrophotometer;
specific conductance--direct measurement, conductivity probe;
sulphates--turbidimetric, Sulfa Ver IV.

Identification

Identification, labelling and cataloging of the thousands of specimens collected took place in the laboratory. Of the organisms collected, only aquatic insects were identified. Aquatic insects were defined as those having at least one life stage which spent time in or on the water. This definition excluded insects living inside the water-hyacinth plant and those found on the emergent portion of the plant.

I identified the specimens using taxonomic keys and referring to identified specimens at the Florida State Collection of Arthropods and to the original species description and other taxonomic papers. Although most groups lacked keys to nymphal stages, I was able to identify the nymphs of almost all groups after examining many specimens and constructing life series.

Since there are few keys for larval forms (especially to species level), I originally attempted to rear many of the larvae collected. However, the lack of adequate facilities and time to rear these many aquatic larvae with their diverse requirements, and the subsequent loss of some specimens and poor quality of others caused the termination of this approach. Subsequently all larvae were preserved in the field along with the other insects. Some larvae were identified by experts on the groups.

I identified the mayfly (Ephemeroptera) nymphs using Berner's (1950, 1968) keys, and Dr. Lewis Berner of the

University of Florida kindly checked the identifications of some representative specimens.

Dragonfly (Odonata:Anisoptera) nymphs were identified using the keys of Wright and Peterson (1944) and Needham and Westfall (1955). Damselflies (Odonata:Zygoptera) were especially difficult to identify since no comprehensive key to species exists, but by using Walker's (1953) descriptions and other species descriptions as well as characters provided by Dr. Minter J. Westfall of the University of Florida, and by constructing life series, I was able to identify all specimens, including very early instars. Dr. Westfall examined and verified all my odonate specimens.

Aquatic Hemiptera were identified using the keys of Herring (1950a, 1950b, 1951a, 1951b) for most families. Velvet water bugs (Hebridae) were identified using Chapman's (1958) key; water-crawling bugs (Naucoridae) were identified using La Rivers' (1948, 1970) keys and by construction of life series of nymphal stages. Dr. Jon Herring, USDA Systematic Entomology Laboratory, confirmed my identifications of representative specimens of different species of aquatic and semi-aquatic Hemiptera except for the giant water bugs (Belostomatidae), which were checked by Dr. Mencke at the Smithsonian Institution.

Caddisfly (Trichoptera) larvae were determined using Wallace's (1968) key. Dr. Oliver Flint at the Smithsonian checked all my caddisfly identifications. Species level determination was frequently impossible.

Dobsonfly (Megaloptera:Corydalidae) larvae were identified with the keys of Chandler (1956) and Cuyler (1958).

Adult water beetles (Coleoptera), except Hydrochidae, were identified by using Young's keys (1954, 1956, 1963). Hydrochidae were identified by Dr. John L. Hellman of the University of Maryland. The larvae of aquatic beetles could not be easily identified, though Leech and Chandler's (1956) keys in Aquatic Insects of California were of some value in identifying larvae of some families to the generic level. Species level determination was possible only for genera monotypic in Florida. Dr. Paul J. Spangler of the Smithsonian Institution graciously identified or confirmed my identifications of all aquatic beetle larvae except Helodidae. Helodidae larvae are very poorly known and even the identification of adults was very difficult. I was successful in rearing some larvae to adult stage. Dr. Dale Habeck, University of Florida, and I were then able to find characters to discriminate the different genera. Dr. Frank Young at the University of Indiana checked all of my aquatic beetle adults except the adult Hydrophilidae, which were checked by Dr. Spangler.

Dr. Dale Habeck also identified the aquatic Lepidoptera larvae.

Mosquito larvae (Culicidae) were readily identified to species using Carpenter and LaCasse (1955). Dr. William Beck of Florida A & M graciously identified all thousand-odd of my midge (Chironomidae) larvae specimens. Other families of

Diptera larvae could be identified to the generic level using keys of Wirth and Stone (1956), while a few (17 specimens) of Diptera larvae and pupae could be placed only at the family level.

Analyses

After all specimens had been identified and recorded, comparison of the species composition of different collections was desired. With the number of species in a collection ranging from 1-31 and the number of specimens in a collection from 3-373, direct comparisons of species composition of collections was difficult. In ecological studies it is common to represent the numbers of species and their relative distribution by a single statistic, an index of species diversity.

The choice of diversity indices is enormous, with much confusion about terms and applicability (Hurlbert 1971, Peet 1974). Much of the confusion results from the dual concepts which most, but by no means all, authorities believe an index of diversity should embody. Almost all agree that species richness, the number of species in a sample (sometimes referred to as species number or species count), should be reflected in the species diversity index used. Many researchers, especially outside the field of ecology, in fact tend to equate diversity with species richness, *i.e.*, a collection has "high diversity" because many species are present. However, this reliance exclusively on species richness does not take into account the relative abundances of each species.

The species evenness or equitability concept of diversity stresses these relative abundances, equating high diversity (more properly, high equitability) with an even distribution of individuals among the species present, while low equitability implies a few abundant species, other species being relatively rare. Most authorities in this area agree that a proper measure of species diversity includes both species richness and species equitability components (Margalef 1969, Pielou 1969, Peet 1974). Hurlbert (1971), among others, would restrict the term diversity to this dual concept.

Because of the preponderance of authoritative opinion favoring a diversity index with both richness and evenness components, classed by Peet (1974) as heterogeneity indices, my investigations were limited to this type.

Peet (1974), in his excellent review article on diversity indices, lists 4 commonly used heterogeneity indices. E. H. Simpson proposed a diversity index in 1949 which recognized the dual concept of diversity and which bears his name. Simpson's index, with slight modifications, is extensively used and is recommended, at least for certain applications, by many authorities (Williams 1964, Whittaker 1965, 1972, Sanders 1968, Pielou 1969). Pielou's (1969) restatement of Simpson's index as adjusted for finite sample size is frequently used:

$$D = 1 - \sum_{i=1}^{s} \frac{n_i(n_i-1)}{N(N-1)} \quad ,$$

where N is the total number of specimens in the collection, n_i is the number of specimens in the $i^{\underline{th}}$ species, and s is the number of species in the sample.

McIntosh (1967) suggested another index:

$$D_{mac} = \sqrt{\Sigma n_i^{\,2}} \quad .$$

McIntosh's index, while receiving attention in review articles on diversity indices (Pielou 1969, Peet 1974), does not appear to be frequently used. Peet (1974) considers it a variation of Simpson's index, while Bullock (1971) criticizes its applicability and sensitivity.

By far the most popular and widely used index is Shannon-Weaver's diversity index:

$$H' = -\sum_{i=1}^{s} p_i \log p_i ,$$

where p_i is the proportion of the total specimens comprised by the $i^{\underline{th}}$ species of $p_i = n_i/N$. Based on information theory, diversity is equated to uncertainty. As Pielou puts it:

> Diversity in this connexion means the degree of uncertainty attached to the specific identity of any randomly selected individual. The greater the number of species and the more nearly equal their proportions, the greater the uncertainty and hence the diversity. (1966a, p. 131)

Although the most popular diversity index, the Shannon-Weaver index is also the most widely criticized. Monk (1967) and Sager and Hasler (1969) believe this index to be insensitive to rare species whereas Peet (1974) suggests it is most sensitive to rare species. Fager (1972), Whittaker (1972) and Poole (1974) believe Shannon's index most sensitive to species of intermediate importance. Pielou (1966b) believes it is used frequently in situations where it is not applicable and questions the validity of equating uncertainty with diversity (1969). Both Pielou (1966a, 1966b) and Peet (1974) agree that the Shannon-Weaver index is applicable only when the collection is a random sample drawn from an infinitely large population pool. For finite collections, such as light-trap collections, Pielou (1966a) suggests the use of Brillouin's (1960) index:

$$H = 1/N \log (N!/n_1!n_2!\ldots n_s).$$

Unfortunately, this involves computing very large numbers. Any integer factorial greater than 69! results in a number larger than 10^{100}, which exceeds the capacity of even large, modern computers. Thus, direct calculation of this index for larger collections is laborious unless a simplifying method such as Sterling's approximation to the factorial is employed. However, the substitution of the Sterling's approximation for the factorial results in this index becoming equivalent to the Shannon-Weaver index (Peet 1974).

Hurlbert believes that ". . . the recent literature on species diversity contains many semantic, conceptual and technical problems", so many problems, in fact, that he concludes ". . . species diversity has become a nonconcept." (1971, p. 57) He would possibly retain the term if the meaning of species diversity were restricted to those terms which combine both species richness and species evenness, *i.e.*, heterogeneity indices. He believes that there are 2 useful indices, one of which is modification of the rarefaction index $E(S_n)$ proposed by Sanders (1968). This index calculates the expected number of species, $E(S_n)$, the sample would contain if the number of specimens were scaled down, *i.e.*, rarefied, to some common number which would allow comparison with other samples. The scaling, which was done incorrectly by Sanders (Hurlbert 1971, Fager 1972, Simberloff 1972), is necessary because larger samples would contain more species than a smaller one even if they were drawn from the same community. Hurlbert (1971) and Simberloff (1972) provide similar, correctly "scaled", calculating formulae for the rarefaction index:

$$E(S_n) = \sum_{i=1}^{s} [1 - \binom{N - n_i}{n} / \binom{N}{n}].$$

While this results in a scaled estimate of species richness, and Peet (1974) classifies this as a richness index, I believe it can be classified under the heterogeneity indices since the species composition, *i.e.* the evenness, was used in the scaling.

I chose the following species diversity indices: Shannon-Weaver index, H', since it is the most commonly used index in recent ecological literature; Simpson's index, D, since it overcomes some of the shortcomings of H'; and the rarefaction diversity index, $E(S_n)$, because of its inherent rationality and ease of interpretation. I wrote a small Fortran program, shown in Appendix A, which calculates

Shannon's H', Simpson's D, and also Brillouin's H when the collection is small enough. For these diversity indices, the choice of the base for the logarithm is left up to the researcher. Since no particular base seems to have become standardized, I chose to use natural logarithms, although the base 2 and base 10 logarithms also are frequently used. For calculating $E(S_n)$, I modified slightly a program cited in Simberloff (1972) and Heck et al. (1975) and provided by Dr. Heck of Florida State University. As a check on the sensitivity of these 3 indices, I also used a fourth, extremely simple index, the number of specimens per species, in all my analyses of diversity.

Efficiency of sampling method and determination of the total number of species in the community sampled are usually unanswered questions in ecological studies. A relatively crude, frequently employed estimate of sample effort (Wilhm 1972, Heck et al. 1975) is the graphical plotting of a species accumulation curve. The cumulative number of new species is plotted versus the cumulative number of specimens, with each collection being added sequentially, hopefully resulting in a curve such as that shown in Figure 1.

The resultant points initially form a straight line, as each collection adds a relatively constant increment of species per specimens collected. However, with increased sampling only rare species remain, and the line rapidly curves to become asymptotic at the value of the total number of species in the community and produces the typical exponential

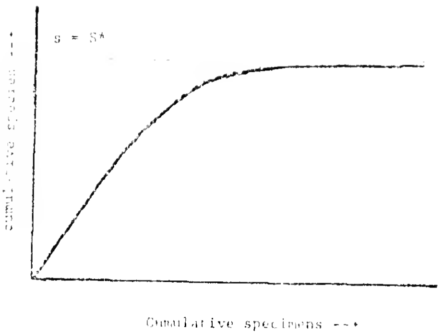

Figure 1. Generalized species accumulation curve.

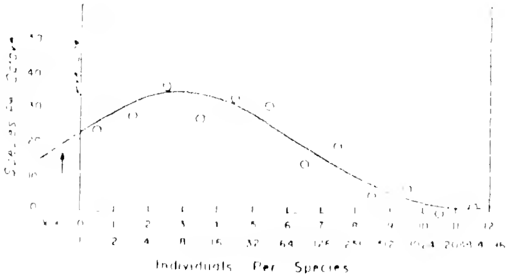

Figure 2. Lognormal species abundance curve (from Preston, 1948).

species accumulation curve. Unfortunately, this asymptote is frequently attained only when the total number of individuals sampled is very large, sometimes only when nearly every individual in the community has been collected and identified. In general practice, most researchers use this method to determine if future sampling will be worthwhile, i.e., whether the crest or some other previously determined point on a species accumulation curve has been reached. This is usually done through simple visual inspection of a graph. The asymptote level, i.e. total number of species, is not usually calculated.

For my data from my 3 repetitively sampled study sites, I refined this procedure. A curve such as the one shown in Fig. 1 can be represented by the general exponential equation:

$$y = a(1 - e^{-bn}),$$

where a is the asymptote for the curve. Rewritten in terms of the species notation previously used, this equation becomes:

$$s = S^* (1 - e^{-bn}).$$

The estimated total number of species in the collecting area, S^*, and the constant, b, can be determined from a curve fitted to the data. Although the computer program SAS PROC NLIN will fit this general curve to the data, it requires estimates of both S^* and b. While a very general approximation of the value for S^* can be obtained from inspection of the data, the approximate value for b is not readily apparent. However, I was able to devise a graphical method for obtaining an estimate for the value of b, which in turn allowed an estimation of S*. First rewriting the equation as:

$$s = S^* - S^*e^{-bn},$$

then taking the derivative results in:

$$ds = bS^*e^{-bn}dn$$

or, in terms of the slope, ds/dn, of the curve:

$$ds/dn = bS^*e^{-bn} .$$

Taking the natural logarithm of both sides results in the expression:

$$\ln(ds/dn) = \ln(bS^*) + (-bn).$$

Thus the logarithm of the slope fits the general equation for a straight line:

$$y = \beta_0 + \beta_1 x,$$

where the intercept β_0 equals $\ln(bS^*)$, and the slope β_1 equals $-b$. The slope ds/dn of the original equation can be approximated by $\Delta S/\Delta n$, the increase in the number of cumulative species over the number of specimens added with each additional collection. Thus, plotting $\ln(\Delta s/\Delta n)$ against the cumulative number of specimens, n, approximates plotting $\ln(ds/dn)$ versus n. Fitting a straight line to the resultant points by using the least squares procedure provides the value β_1, which is a good approximation of b. Plugging this value of b and the values of a pair of s and n back in to the original equation results in a point estimate of S*. Using these crude estimates of S* and b allows the use of PROC NLIN to fit the curve to the data point, which then gives precise estimation of S* and b. The goodness of fit of the curve to the data points can be demonstrated by noting the level of significance for the F value, calculated by dividing the mean square of the regression by the mean square of the residual. Sampling efficiency was then simply the actual number of species collected (s) over the expected number of species (S*) or:

$$\text{sampling efficiency} = s/S^*.$$

Another semigraphical method for determining the total number of species (S*) is by plotting what is termed a species abundance curve. F. W. Preston first presented this method in 1948 and elaborated on it in 1958 and 1962. The data are first arranged according to abundance of individuals in each species. The species are then grouped, each successive group representing species with twice as many individuals as the preceding group or, in other words, on a base 2 logarithmic scale. The third "octave," Preston's term for the groups, represents species which have between 4 and 8 individuals. Any species which falls on an interval boundary is split equally between both octaves, thus a species containing 4 specimens is counted as contributing one-half to the second octave (2-4 individuals) and one-half to the third octave

(4-8 individuals). Thus the first octave contains half of the species having a single specimen and half of the species having 2 specimens. The number of species per octave is then plotted against the octave, resulting in a curve such as that shown in Fig. 2, representing the species and abundances of moths caught in a light trap, as presented by Preston (1948). Note that the left-hand portion of the curve ends abruptly at the y-axis, called the "veil line" by Preston. The species to the left of the veil line are those which would be represented by less than a single individual if collected in the same proportion as they exist in the sampling area, and they are, therefore, "hidden by the veil line," to use Preston's terminology. The general equation of the Gaussian curve which Preston fits to this and other data is:

$$s = s_o e^{-(aR)^2}$$

where s_o is the number of species in the modal octave, R_o (the octave containing the most species), s is the number of species in an octave which is R octaves from the modal octave, and a is ". . . a constant calculated from the experimental evidence" (p. 258). In practice, a is extremely difficult to determine. It is derived by solving the equation for the curve which has been fitted to the data. Unfortunately, fitting a truncated Gaussian curve is a very difficult task. The statisticians in the Department of Statistics at the University of Florida are awaiting arrival of some special statistical tables to enable them to do this. Although most texts dealing with mathematical ecology (Cody and Diamond 1975, Pielou 1969, Price 1975, Poole 1974) mention Preston and present his graphs, I have found very few authors (Good 1953, Patrick 1954) who are able to apply his techniques to their own data. However, the value of a has been found to be very close to 0.2 for all data analyzed by Preston (1948, 1958, 1962). The total number of species in the sampling area S* can then be found from the relation:

$$S^* = s_o \sqrt{\pi} / a$$

As Preston (1948) carefully points out, this theoretical total number of species is really the total number of species in the sampling universe, which differs from the total number of species in the sample area. It represents the total number of species which would be found if all individuals collectible by the sampling methods used were collected during the sample period. For example, the number of species estimated from light-trap data represents only those species which are in the vicinity of the light trap and are attracted or blunder into it. It does not represent the total number of species of all moths in the collecting area, just the collectible species.

For purposes of comparison, species abundance curves were fitted by eye to the data for my 3 study sites and the value of a was assumed to equal 0.2. While extremely rough, the S* derived by this method can be compared to S* derived from the species accumulation curves.

For other analyses of my data I used the 76.4 version of a variety of statistical computer programs which collectively are known as SAS (Barr *et al*. 1976). The most commonly used statistical procedures were standard descriptive statistics (PROC MEAN), correlation (PROC CORR), linear regression (PROC GLM), stepwise multiple regression (PROC STEPWISE), nonlinear regression (PROC NLIN), and discriminant analysis (PROC DISCRIM). Standard printing and plotting programs (PROC PRINT and PROC SCATTER) were also used. All computer analyses were done by the IBM 370/165 computer (later replaced by an AMDAHL 470 V/6) at the Northeast Regional Data Center (NERDC) on the University of Florida campus.

Because of the great variety of analyses, the results will be discussed under three separate headings: general, study site comparison, and diversity studies.

RESULTS AND DISCUSSION

General

Comments on Species List

A total of 5485 aquatic insects were found in 88 collections from 37 sites in 18 Florida counties. Table 1 presents a list of collections, locations and dates. Some immature forms could be identified only to genus level, while 17 specimens of immature Diptera could be placed only to family level. Represented in the collections were at least 147 species of aquatic insects belonging to 44 families in 8 orders. Of these 147 species, 38 were represented by more than one life stage. These immature forms were treated as separate classes in all analyses except those involving species counts. An annotated list of all species collected is presented in Table 2. The species are arranged according to taxonomic groups; the orders are arranged in the same evolutionary sequence as in Usinger (1956). Within the orders the families are arranged alphabetically, as are the genera and species within the families. For each species the number of specimens collected, the number of sites and counties, as well as a list of collection numbers is presented. Any significant correlations with physical or chemical parameters as well as associations with other insect species are noted. Maximum densities

(text continued p. 116)

Table 2. An annotated list of insects collected in waterhyacinth roots in Florida.

Note: All correlations were computed using normalized (log transformed) data. For each species under the categories "water quality preference" and "insect associations" is listed (1) the factor or species with which the species being discussed is correlated; (2) the correlation coefficient, r; (3) p, the probability that the correlation coefficient observed would occur by chance alone; and (4) n, the number of times the pair of factors or species being considered occurred together. Only associations with a probability less than 0.05 (5%) of occurring by chance are mentioned. While the probability p takes into account the number of observations, it is overly sensitive at low values of n. Correlations which have less than 5 paired observations ($n<5$) therefore have not been included. Maximum density per square meter is given for species collected using 0.2 square meter sampler.

Ephemeroptera (Mayflies)--Nymphs

Only 150 mayfly nymphs of 4 different species were found. Constituting only 2.7% of the total insects collected, they were never very numerous except in collection #87, where 31 specimens of 3 species made up 41.9% of the specimens collected there. Katz (1967) mentions collecting the genera Brachycerus, Cloeon, and Hexagenia in addition to Caenia from hyacinths in the Withlacoochee River. The first two genera are probably misidentifications due to their distribution and ecological requirements. O'Hara (1961) collected Callibaetis floridanus and Caenis diminuta from waterhyacinth-covered canals in South Florida.

Baetidae

1. Callibaetis floridanus Banks--45 specimens from 12 collections at 8 different locations in 6 counties.

Collections: 2, 20, 21, 45, 48, 50, 75, 82, 87, 88, 98, 102.

Maximum density: .6/plant or 30/m^2 at #87.

Water quality preference: nitrates, r=-.859, p=.028, n=6.

Nymphs of *C. floridanus*, known to inhabit brackish water, ". . . have the widest limits of toleration of any mayfly nymph in North America" (Berner 1950, p. 196). Although this species was collected numerous times in waterhyacinth roots by myself and by O'Hara (1961), Berner (1950) does not believe them common inhabitants of waterhyacinths due to low oxygen levels.

I collected the majority of nymphs of *C. floridanus* during the summer, especially August. Some were also collected in November through January. The absence of nymphs during the other six months may indicate a bivoltine life pattern.

C. floridanus' high correlation with Shannon-Weaver's diversity index (r=.666, p=.018, n=6) may indicate that it is especially sensitive to conditions which help increase the diversity of species at the site. This is supported by the highly significant correlation to number of species (r=.745, p=.006, n=12). The high negative correlation to the nitrate level, one of the chief causes of eutrophication, and the high negative correlation to number of plants per square meter (r=-.963, p=.002, n=6) also points this out.

The relative numbers of this species might, therefore, find use as an indicator of water quality.

2. *Callibaetis pretiosus* Banks--14 specimens in 4 collections from 2 different locations in Alachua Co.

Collections: 36, 42, 50, 87.

Maximum density: .25/plant or $12.5/m^2$ at #87.

Berner (1950) believes *C. pretiosus* to have similar ecological requirements as *C. floridanus* except that it is not quite as tolerant to high and low pH and to brackish water.

Caenidae

3. *Caenis diminuta* Walker--75 specimens from 24 collections at 13 different locations in 10 counties.

Collections: 2, 3, 5, 26, 27, 31, 45, 48, 52, 75, 80, 82, 85, 87, 88, 89, 92, 93, 94, 97, 98, 100, 102, 103.

Maximum density: .7/plant or $35/m^2$ at #87.

Insect associations: *Hydrocanthus oblongus* Sharp, r=.841, p=.002, n=10.

My most commonly collected mayfly, it is also recorded by O'Hara (1961) and is probably the *Caenis* sp. collected by Katz (1967). According to Berner (1950), this species prefers small ponds, especially with emergent vegetation, but is usually not found in water covered by waterhyacinths.

There is an extremely significant correlation with the noterid beetle *Hydrocanthus oblongus* which probably indicates that these species prefer the same set of environmental conditions.

Nymphs were collected throughout the year.

Heptageniidae

4. Stenacron interpunctatum (Say)--16 specimens from 8 collections at 2 locations in Alachua Co.

Collections: 31, 35, 38, 39, 50, 53, 56, 73.

Maximum density: .129/plant at #35; 2/m^2 at #73.

Formerly known as Stenonema proximum, S. interpunctatum nymphs are usually inhabitants of large streams and sand-bottomed lakes with little vegetation. Dr. Berner (personal communication) finds their existence in waterhyacinth roots to indicate a possible broadening of the species' ecological requirements.

Most of my specimens were collected during the fall and winter months.

Odonata (Dragonflies and Damselflies)--Nymphs

Odonata were well represented with 1,027 specimens (18.7% of the total specimens) in 18 species. Odonates made up at least half of the specimens in many collections and constituted 75% of the specimens in collection #102. Odonate nymphs were the most common arthropod group in Wahlquist's (1969) study of fish food organisms in experimental ponds in Auburn, Alabama.

Since all odonate nymphs are predaceous, their abundance implies a large prey population. The most probable prey item, at least in numbers, would be the amphipod Hyalella azteca (Saussure). Hansen et al. (1971) reports 66 amphipods per waterhyacinth plant, but in the field they were probably more numerous, with a bucketful of water frequently containing literally thousands of amphipods. O'Hara (1961) recorded as many as 81,000 per square meter at one site.

Zygoptera (Damselflies) Nymphs

This suborder, with 752 specimens, comprised 13.7% of all specimens and 73.2% of all odonates. Damselfly nymphs were found in most collections, with one species, *Ischnura posita*, being found in 53.4% of my collections, making it the most frequently represented species. While only 7 species and the *E. signatum-pollutum* complex were found, 5 of these were collected over 8 times as compared to only 3 out of the 11 species of Anisoptera nymphs. O'Hara (1961) found *Ischnura ramburii* (Selys) and *Enallagma* sp. nymphs beneath waterhyacinths in canals, while Katz (1967) records 4 genera of damselflies from waterhyacinth roots at the Withlacoochee River.

Coenagrionidae

Of the 3 families of damselflies known from Florida, this was the only one which was found beneath waterhyacinths. Of the 35 species in this family that occur in Florida (Johnson and Westfall 1970), 7 were collected in waterhyacinth roots.

5. *Argia apicalis* (Say)--1 specimen collected at Lake Talquin, Gadsden Co.

Collection: 96.

Density: .05/plant; 5/m^2.

Due to the rarity of this species in my collections, no significant conclusions can be drawn concerning its preferences or associations. While usually considered a stream species (Walker 1953), it has been recorded from ponds in Indiana (Montgomery 1944).

6. Argia sedula (Hagen)--39 specimens from 3 locations in 3 counties.

Collections: 48, 102, 103.

Maximum density: .769/plant at #48; 35/m^2 at #103.

This species was rarely collected. Walker (1953) states that the habitat of this species is "streams with gentle current and rich vegetation on the banks" (p. 144). All 3 times I collected this species were in streams and rivers of South Florida during mid December of 1973 and 1974.

7. Enallagma pollutum (Hagen)--24 specimens from 8 collections at 2 places in Alachua Co.

Collections: 17, 18, 31, 38, 72, 75, 82, 94.

Maximum density: .364/plant at #17; 7.5/m^2 at #75.

Nymphs of this species are extremely difficult to distinguish from E. signatum nymphs. Only larger, last instar nymphs could be separated with confidence by counting the number of spines on the caudal lamellae. Smaller nymphs were classed as belonging to the Enallagma signatum-pollutum complex. No water quality preferences for this species were noted. All but 3 specimens were collected from Camps Canal east of Micanopy. All were found between mid-May and mid-November. Since this species has a significant, negative correlation with Simpson's diversity index (r=-.826, p=.012, n=8), it may be a low diversity indicator.

8. Enallagma signatum (Hagen)--25 specimens from 9 collections at 4 locations in 2 counties.

Collections: 38, 42, 50, 53, 56, 75, 87, 96, 99.

Maximum density: .35/plant and 35/m^2 at #96.

With only last instar nymphs distinguishable from E. pollutum, this species was collected mainly from November through February. A strong negative correlation (r=.774, p=.022, n=9) with the number of species may indicate that older nymphs of this species would not be expected at a place which has numerous species.

Enallagma signatum-pollutum complex--119 specimens from 22 collections at locations in 6 counties.

Collections: 2, 3, 17, 18, 27, 31, 35, 38, 42, 45, 48, 50, 56, 72, 73, 75, 78, 83, 94, 96, 102, 103.

Maximum density: .515/plant at #17; 35/m^2 at #102.

Water quality preferences: pH, r=.740, p=.023, n=9; temperature, r=.755, p=.050, n=7; depth, r=-.519, p=.019, n=20; chloride, r=.880, p=.004, n=8; potassium, r=.866, p=.005, n=8.

Insect associations: Hydrocanthus oblongus Sharp, r=.655, p=.040, n=10.

Young Enallagma nymphs which could be determined as belonging to either E. pollutum or E. signatum but whose exact species remained unknown due to their small size and undeveloped diagnostic characters were placed in this group. This species complex was found in shallower water which was high in chlorides and potassium and had a high pH. It was correlated with the presence of H. oblongus. These nymphs were collected throughout the year.

9. Ischnura posita (Hagen)--319 specimens from 47 collections at 17 locations in 9 counties.

Collections: 2, 3, 4, 7, 11, 13, 17, 20, 21, 27, 32, 35, 38, 40, 41, 42, 43, 45, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 69, 70, 71, 72, 73, 74, 75, 78, 85, 86, 87, 88, 90, 94, 98, 101, 102, 103.

Maximum density: .575/plant at #70; 80/m^2 at #69.

Water quality preference: nitrates, r=-.477, p=.045, n=18.

Insect associations: Belostoma spp. nymphs, r=.779, p=.008, n=10; Pelocoris femoratus (Palisot-Beauvois), r=.806, p=.0001, n=22; Ranatra australis Hungerford, r=-.774, p=.041, n=7.

While it was only the fourth most numerous in specimens collected, I. posita was found in 53.4% of my collections, more than any other species. It was present throughout the year but reached peak density in the spring. It appears to prefer less eutrophic waters, i.e., those with less nitrates. It was generally found when Ranatra australis was present in low numbers and when Belostoma spp. nymphs were abundant. There was an extremely significant correlation with Pelocoris femoratus, with P. femoratus being collected only 7 times in the absence of I. posita. The strength of this association suggests to me that I. posita may be a preferred prey item for P. femoratus and/or they both share a common food resource such as the amphipod Hyalella azteca (as opposed to sharing an uncommon food resource). It is possible that this correlation reflects some unknown symbiotic relationship between these two species. The Ischnura ramburii recorded by O'Hara (1961) may have been misidentified I. posita since the nymphs are very similar and the pigmentation of the caudal lamellae, which is used as a diagnostic character, is quite variable or absent in smaller nymphs.

10. Telebasis byersi Westfall--220 specimens from 26 collections at 8 locations in 4 counties.

Collections: 2, 21, 24, 27, 32, 36, 37, 39, 40, 41, 42, 43, 47, 49, 51, 52, 54, 55, 70, 71, 75, 85, 87, 88, 90, 97.

Maximum density: 1.67/plant at #39; 70/m^2 at #97.

Insect associations: Brachyvatus seminulum LeConte, r=-.918, p=.028, n=5; Scirtes larvae, r=-.886, p=.045, n=5.

The second most numerous odonate in my collections, T. byersi was found in 29.5% of my collections, which ranked it as tenth in number of collections in which it was present and sixth in total number of specimens. It was found throughout the year. Florida specimens of this species were thought to be Telebasis salva until Westfall described T. byersi in 1957. While there are significant negative correlations with 2 species of aquatic beetles, no water quality preferences were noted. Since T. byersi keys out as belonging to the genus *Nehalenia* in most keys, it is probable that the *Nehalenia* recorded by Katz (1967) from waterhyacinth roots was really *T. byersi*.

Anisoptera (Dragonflies) Nymphs

With 275 specimens (5% of the total specimens collected), this suborder was not as numerous as the damselflies and made up only 26.7% of the odonates collected. However, while damselflies were represented by 1 family and 7 species, 11 species in 5 different families of anisopterans were collected. Of these anisopteran species, 5 are represented by only one specimen and only 3 species were collected more than 3 times. While usually not numerous, they were occasionally abundant, comprising 66.4% of the 122 specimens found at collection #102.

O'Hara (1961) collected 5 species of Anisoptera from waterhyacinth-covered canals while Katz (1967) records 8 different species. I collected 4 species in common with O'Hara but did not find any *Brachymesia* (=*Cannacria*) *gravida* (Calvert). While I collected only 3 species in common with Katz, several of her determinations are suspect, *e.g.* *Dythemis* sp. and *Nannothemis bella* are both thought to be found in Florida only in the western panhandle region.

Aeshnidae

With only 5 specimens in 3 species, this family was rarely found beneath waterhyacinths and neither O'Hara (1961) nor Katz (1967) record any aeshnid species.

11. _Anax junius_ (Drury)--1 specimen collected at Camps Canal in December 1973.

Collection: 42.

Density: .31/plant.

12. _Boyeria vinosa_ (Say)--1 specimen collected in a stream in December 1973.

Collection: 47.

Density: .026/plant.

13. _Coryphaeschna ingens_ (Rambur)--1 specimen collected at Camps Canal in December 1973.

Collection: 42.

Density: .031/plant.

Byers (1930) records this species from waterhyacinth.

14. _Nasiaeschna pentacantha_ (Rambur)--3 specimens from 3 collections at 2 locations in 2 counties.

Collections: 35, 45, 50.

Maximum density: .077/plant at #45.

Cordulidae

15. _Tetragoneuria cynosura_ (Say)--2 specimens from 2 collections at a small stream in Alachua Co.

Collections: 27, 87.

Maximum density: .05/plant or 2.5/m^2 at #87.

This genus is now considered by some authorities to be part of _Epitheca_. Both O'Hara (1961) and Katz (1967) collected _Tetragoneuria_ sp. from waterhyacinths.

Gomphidae

Most members of this family are burrowing forms and are rarely found beneath waterhyacinths.

16. Aphyla williamsoni (Gloyd)--1 specimen collected at Camps Canal on 29 May 1974.

Collection: 73.

Density: .997/plant or $1/m^2$.

The one specimen I found of this species was a fully developed nymph from which the adult was starting to emerge, indicating that it had been knocked into the water from the aerial portion of the plant where emergence was taking place. This species lives on the bottom and may be present on waterhyacinth roots only when moving out of the water for emergence. Katz (1967), however, also recorded this species in one of her collections.

Libellulidae

With 266 specimens in 5 species, libellulids were well-represented. Two of the species were my tenth and eleventh most abundant overall. Of the Anisoptera I collected, 96.7% were members of this family.

17. Erythemis simplicollis (Say)--36 specimens in 9 collections at 9 locations in 4 counties.

Collections: 2, 3, 13, 21, 45, 47, 83, 86, 87.

Maximum density: .615/plant at #45; $40/m^2$ at #85.

This species was not usually very abundant in my collections, but 18 of the 29 odonate nymphs found by O'Hara

(1961) in waterhyacinth mats were _E_. _simplicollis_. My specimens were all collected in late summer or during December.

18. _Miathyria_ _marcella_ (Selys)--116 specimens from 10 collections at 9 locations in 6 counties.

Collections: 5, 7, 20, 30, 31, 47, 75, 88, 100, 102.

Maximum density: 5/plant or 400/m^2 at #102.

While this was my most abundant Anisoptera nymph, 69% of all the specimens of this species were found in collection #102. O'Hara (1961) recorded this species. Katz (1967) did not report this species, possibly due to its absence from the keys she used. Byers (1930) did not find this tropical species in Florida, while today this is one of our more common species. It would be interesting to compare the overlap of distribution of this recently introduced species with that of waterhyacinth. I collected nymphs of this species only between June and December.

19. _Pachydiplax_ _longipennis_ (Burmeister)--111 specimens in 30 collections from 15 locations in 8 counties.

Collections: 2, 4, 7, 13, 29, 30, 31, 35, 36, 38, 42, 45, 47, 51, 53, 54, 56, 57, 69, 70, 75, 79, 83, 85, 87, 88, 94, 95, 97, 103.

Maximum density: .391/plant at #51; 37.5/m^2 at #85.

Water quality preference: iron, r=.900, p=.014, n=6.

Insect associations: _Pelocoris_ _femoratus_, r=-.554, p=.050, n=13.

While not overly abundant at any location, this species was widely distributed, and among the odonates, only *Ischnura posita* was found in more collections. Among all my specimens, *P. longipennis* ranked seventh in the number of collections in which it was found and eleventh in overall abundance. Nymphs were collected throughout the year, usually at locations which had a high iron content and harbored low populations of *Pelocoris femoratus*. Not surprisingly, both O'Hara (1961) and Katz (1967) report this species from their waterhyacinth collections.

20. *Perithemis tenera* (Say)--1 specimen collected at Lake Lawne in Orlando on 13 July 1973.

Collection: 26.

Density: .033/plant.

Macromiidae

Frequently considered as a subfamily of the family Libellulidae, nymphs of this family are bottom sprawlers and were infrequent in my collection.

21. *Macromia taeniolata* Rambur--2 specimens from 2 collections in 2 counties.

Collections: 102, 103.

Maximum density: .062/plant or 5/m^2 at #102.

Both specimens were found in mid-December.

Hemiptera (True Bugs)--Adults and Nymphs

While aquatic hemipterans, with 504 specimens, comprised only 9.2% of my total specimens, they represent 10 different families and at least 22 species. The contribution of aquatic Hemiptera to the diversity (at least the richness component of diversity) of a collection was relatively great. Only the aquatic beetles and Diptera could equal the large number of different families in my collections. While sometimes locally abundant, they were usually sparsely distributed.

O'Hara (1961) reported only 2 kinds of aquatic Hemiptera: Belostomatidae and Naucoridae. Katz (1967) lists 9 families and 10 genera of aquatic Hemiptera, with Notonecta sp. the only one which I did not also collect.

Since all aquatic Hemiptera (except the Corixidae) are predaceous, their presence should be associated with that of a suitable prey organism, most probably the amphipod Hyalella azteca.

Belostomatidae (Giant Water Bugs)

With 82 specimens, the 3 species of Belostomatidae comprised 16.3% of the total Hemiptera collected and were my second most abundant hemipteran family. They were usually not particularly abundant at any one site, averaging less than 4 specimens whenever found. However, they did constitute 26.6% of the 60 specimens in collection #54. Both O'Hara

(1961) and Katz (1967) as well as Hansen et al. (1971) mention collecting Belostoma spp. in waterhyacinth roots.

22. Belostoma lutarium (Stal)--12 specimens in 11 collections from 4 locations in 3 counties.

Collections: 18, 36, 70, 71, 72, 75, 88, 94, 95, 96, 103.

Maximum density: .18/plant or $10/m^2$ at #94.

Adults of this species were never abundant, more than one specimen being collected only once. My specimens were all collected between May and December.

This species was strongly correlated with all the diversity indices except Simpson's index. The Shannon-Weaver index for collections in which this species was found averaged at a relatively high 2.26. The presence of this species might be used as an indicator of high diversity of insect fauna in waterhyacinth-covered waters.

23. Belostoma testaceum (Leidy)--17 specimens in 10 collections at 5 locations in 2 counties.

Collections: 7, 11, 19, 22, 33, 37, 40, 54, 90, 94.

Maximum density: .333/plant at #37; $10/m^2$ at #94.

Most of my specimens (65%) came from a drainage culvert along Interstate 75 north of Micanopy. Except for 2 specimens found in February, all were collected from June through November.

Belostoma spp. nymphs--52 specimens in 16 collections at 5 locations in 3 counties.

Collections: 3, 22, 33, 35, 52, 54, 57, 71, 75, 78, 79, 86, 88, 89, 91, 92.

Maximum density: .833/plant at #22; 15/m^2 at #75.

Insect associations: Ischnura posita, r=.779, p=.008, n=10; Chironomus attenuatus Walker, r=-.661, p=.052, n=9.

Since only the adults of this genus could accurately be placed at species level, all nymphs of the genera were placed in this category. Nymphs were collected from February through October.

24. Lethocerus uhleri (Montandon)--1 specimen collected at Camps Canal in October 1973.

Collection: 35.

Density: .031/plant.

Corixidae (Water Boatmen)

All specimens were collected at Otter Creek, Levy Co., in July of 1973.

Collections: 20, 21.

Maximum density: .154/plant at #21.

While the 2 adults appear to be Trichorixa sp., the other specimen is a nymph and cannot be keyed. Members of this family are rare among waterhyacinths and were all collected at one location. They were not reported by either O'Hara (1961) or Katz (1967).

Gerridae (Water Striders)

These surface-film forms were rare in my collections. Although present at the collection sites, they generally seem to prefer more open water than that found between waterhyacinth plants. Only a total of 6 specimens of this family were collected.

26. *Gerris canaliculatus* (Say)--only 1 specimen collected at a small stream near Gainesville in August 1974.

Collection: 87.

Density: .05/plant or 2.5/m^2.

27. *Limnogonus hesione* (Kirkaldy)--only 1 specimen collected at Otter Creek in Levy Co. in July of 1973.

Collection: 21.

Density: .977/plant.

Katz (1967) reports collecting *Limnogonus* sp. in waterhyacinth roots.

28. *Trepobates* sp.--only 1 specimen collected with *L. hesione* (above).

Collection: 21.

Density: .977/plant.

Unidentified gerrid nymphs--3 specimens from 3 locations in 2 counties.

Collections: 20, 38, 75.

Maximum density: .045/plant at #38 and 2.5/m^2 at #75.

Hebridae (Velvet Water Bugs)

These small insects, less than 2.5mm long, are inconspicuous and frequently overlooked since, unless they are moving, they appear to be pieces of debris. A total of 21 specimens in 4 species were collected, all of them in Alachua Co. Katz (1967) records *Hebrus* sp. from waterhyacinths in the Withlacoochee River.

29. *Hebrus burmeisteri* (L. & S.)--4 specimens from 3 locations in Alachua Co.

Collections: 30, 54, 72.

Maximum density: .971/plant at #54; 1.0/m^2 at #72.

30. Hebrus consolidus Uhler--5 specimens from 5 locations in Alachua Co.

Collections: 15, 16, 49, 54, 70.

Maximum density: .048/plant at #49; 1.67/m^2 at #70.

All my specimens of this species were collected between January and July.

31. Merragata brevis Champion--only 1 specimen from Camps Canal in May of 1974.

Collection: 70.

Density: .014/plant or 1.66/m^2.

32. Merragata brunnea Drake--11 specimens in 4 collections from 3 locations in Alachua Co.

Collections: 15, 29, 75, 85.

Maximum density: .083/plant at #15, 7.5/m^2 at #85.

All my specimens of this species were collected during the summer months.

Hydrometridae (Water Measurers)

With only 18 specimens distributed between 2 species, this family was never particularly abundant. Katz (1967) reports finding them in 2 of her collections.

33. Hydrometra myrae Bueno--11 specimens from 7 collections, all at Camps Canal.

Collections: 31, 69, 70, 72, 73, 95, 99.

Maximum density: .235/plant or 20/m^2 at #99.

My most common hydrometrid, H. myrae is considered ". . . the most prevalent Hydrometra in the state" (Herring 1948, p.113). My specimens were collected between April and November.

34. Hydrometra wileyi Hungerford--3 specimens in 2 collections from 2 counties.

Collections: 27, 107.

Maximum density: .125/plant or 10/m^2 at #126.

Herring (1948) records this species from only one site in the state. My records add 2 new counties to the distribution of this species.

Hydrometra sp. nymphs--4 specimens from 4 collections at 4 locations in 3 counties.

Collections: 1, 2, 21, 47.

Maximum density: .077/plant at #21.

Mesoveliidae (Water Treaders)

Never very abundant and with only 59 specimens, mesoveliids were found in 30 of my collections, making them the second best hemipteran family for representation in different collections. Katz (1967) also collected some Mesovelia in waterhyacinths.

35. Mesovelia mulsanti White--15 specimens in 10 collections from 7 locations in 4 counties.

Collections: 5, 17, 54, 70, 75, 85, 88, 94, 96, 100.

Maximum density: .091/plant at #94; 10/m^2 at #85.

All the adult mesoveliids I collected belonged to this species. Herring (1951b) records this species from waterhyacinths. There is a strong correlation with root length (r=.813, p=.008, n=9) and high root:shoot ratio (r=.807, p=.009, n=9) for this species. Adults were collected in February and May through April.

Mesovelia sp. nymphs--44 specimens in 23 collections at 10 locations in 4 counties.

Collections: 1, 2, 11, 41, 21, 22, 23, 24, 33, 36, 38, 49, 53, 70, 72, 73, 78, 89, 91, 93, 94, 95, 96.

Maximum density: .227/plant at #38; 15/m^2 at #95.

Insect associations: Myxosargus spp., r=-.746, p=.013, n=10.

Although all mesoveliid nymphs key out to M. amoena Uhler, I classed all these nymphs simply as Mesovelia sp. Dr. Jon Herring at the National Museum considered most (if not all) of my mesoveliid nymphs to be M. amoena, but I consider this unlikely since I collected no M. amoena adults but many M. mulsanti adults. There is a strong positive correlation with the presence of stratiomyid larvae, Myxosargus. These nymphs were collected throughout the year.

Naucoridae (Creeping Water Bugs)

Naucorids were not only the best-represented hemipteran family, being present in 43 collections, but it was also the most numerous hemipteran family, with 194 specimens making up 38.5% of hemipterans collected and 3.5% of the total insects. Both O'Hara (1961) and Katz (1967) record this family, which is represented in the eastern U. S. by 1 genus and 3 species.

36. Pelocoris balius La Rivers--107 specimens from 31 collections at 9 locations in 3 counties.

Collections: 7, 11, 14, 15, 17, 19, 23, 24, 31, 32, 35, 36, 38, 39, 42, 50, 55, 56, 69, 70, 71, 72, 73, 75, 76, 89, 91, 94, 95, 97, 99.

Maximum density: .405/plant at #35; 16/m^2 at #72.

Water quality preference: potassium, r=-.739, p=.009, n=11.

Insect associations: Pelocoris femoratus, r=.490, p=.047, n=17; Hydrovatus larvae, r=.881, p=.048, n=5; Suphisellus insularis (Sharp), r=-.549, p=.052, n=13; Suphisellus puncticollis Crotch, r=.816, p=.048, n=6.

Considered as a subspecies of P. femoratus by La Rivers, P. balius has been elevated to species rank by me since the 2 species were collected together 17 times.

P. balius is associated with low levels of potassium, with P. femoratus, Hydrovatus larvae, and with Suphisellus puncticollis. It is generally found in waters where the numbers of S. insularis are low. It was collected throughout the year, with over 79% of the specimens coming from Camps Canal.

37. Pelocoris femoratus (Palisot-Beauvois)--87 specimens in 29 collections from 8 locations in 2 counties.

Collections: 3, 11, 31, 35, 38, 40, 42, 50, 53, 55, 56, 69, 70, 71, 72, 73, 74, 75, 78, 81, 83, 85, 86, 88, 89, 93, 95, 99, 102.

Maximum density: .205/plant or 25/m^2 at #70.

Insect associations: *Ischnura posita*, r=.806, p=.0001, n=22; *Pachydiplax longipennis*, r=-.554, p=.050, n=13; *Pelocoris balius*, r=.471, p=.057, n=17; *Ranatra australis* Hungerford, r=-.920, p=.010, n=6.

This species also was collected throughout the year, frequently along with *P. balius*, with which it is marginally correlated. There is an extremely significant correlation (p=.0001) with the damselfly nymph *Ischnura posita*, with *P. femoratus* being found only 7 times (out of 29) in the absence of *I. posita*. *P. femoratus* is negatively correlated with the anisopteran *Pachydiplax longipennis* and with the nepid *Ranatra australis*. There is a strong correlation (r=-.601, p=.01, n=17) with plants having fewer leaves. Over 83% of the specimens were collected at Camps Canal.

Nepidae (Water Scorpions)

With 52 specimens in 9 collections, the 3 species of water scorpions collected made up only 10.3% of the hemipterans collected and less than 1% of the total specimens. However, they were sometimes extremely abundant locally, with collection #75 averaging 75 specimens/m^2. Neither O'Hara (1961) nor Katz (1967) records any water scorpions from their collections.

38. *Ranatra australis* Hungerford--35 specimens in 10 collections from 4 locations in 3 counties.

Collections: 3, 17, 73, 75, 76, 94, 95, 99, 102, 103.

Maximum density: .484/plant or 75/m^2 at #75.

Water quality preference: nitrates, r=.747, p=.033, n=8.

Insect associations: *Ischnura posita*, r=-.774, p=.041, n=7; *Pelocoris femoratus*, r=-.920, p=.010, n=6.

Herring (1951a) records this ". . . the most prevalent *Ranatra* in Florida" (p. 18) from waterhyacinths. This species was generally found in shallow water which was high in nitrates. It is negatively associated with the presence of either *I. posita* or *P. femoratus*. Almost 43% of my specimens were collected at one time at Prairie Creek in DeSoto Co. Of the remaining specimens, 80% came from Camps Canal. My specimens were all collected from May through December.

39. *Ranatra buenoi* Hungerford--6 specimens collected only at Camps Canal, Alachua Co.

Collections: 70, 73, 94, 95.

Maximum density: .20/plant or 15/m^2 at #95.

This relatively rare species was collected only at Camps Canal in May, October, and November.

40. *Ranatra nigra* Herrich-Schaeffer--11 specimens from 2 collections in 2 counties.

Collections: 102, 103.

Maximum density: .625/plant or 50/m^2 at #102.

Although it was collected only in December at 2 locations in South Florida, it was quite abundant at Prairie Creek, averaging 50 water scorpions per square meter.

Pleidae (Pygmy Back Swimmers)

Although members of this family, which is represented by a single species in the U. S., prefer dense, tangled vegetation, they were never common in my collections.

41. *Neoplea striola* (Fieber)--22 specimens in 9 collections from 4 locations from 2 counties.

Collections: 3, 18, 36, 53, 71, 75, 87, 88, 97.

Maximum density: .50/plant or $25/m^2$ at #97.

Water quality preference: potassium, r=.910, p=.032, n=5.

Formerly known as *Plea striola*, this species was associated with waters high in potassium and having a low Simpson's diversity index, with 59% coming from Lake Alice. Katz (1967) recorded this species from 2 of her collections. Although they were found throughout the year, 64% of the specimens were collected during the summer months.

Veliidae (Broad-Shouldered Water Striders)

With 47 specimens distributed between 2 species, this family was never common, averaging less than 2 specimens when found, but it was well-represented, being present in over 30% of my collections. Thus, although they comprise less than 1% of the total insects collected, their contribution to the diversity of the collection is important.

42. *Microvelia borealis* Bueno--25 specimens in 15 collections from 12 locations in 4 counties.

Collections: 1, 2, 15, 16, 19, 21, 23, 24, 25, 34, 43, 44, 53, 72, 75.

Maximum density: .095/plant at #16; $2.5/m^2$ at #75.

Katz (1967) recorded this genus in her collections.

43. Velia brachialis Stal--22 specimens in 13 collections from 5 locations in 4 counties.

Collections: 17, 18, 21, 31, 35, 38, 42, 50, 87, 90, 95, 102, 103.

Maximum density: .182/plant at #38; $10/m^2$ at #103.

Velia is negatively correlated with number of leaves per plant (r=-.933, p=.020, n=5).

Almost 73% of the specimens came from Camps Canal. Katz (1967) reports this genus from her collections.

Trichoptera (Caddisflies) Larvae

Only 16 caddisfly larvae belonging to 2 species were found during this study and 15 of these came from the same location. Although from my collections Trichoptera would appear to be rare, O'Hara (1961) reports a probable 3 different, unidentified species while Katz (1967) recorded 5 different groups in her survey.

Leptoceridae

44. Oecetis prob. cinerascens (Hag.)--6 specimens in 4 collections from 2 locations in Alachua Co.

Collections: 3, 35, 50, 87.

Maximum density: .05/plant or $2.5/m^2$ at #87.

All but one of my specimens came from Camps Canal and all were collected in August and September except for one specimen collected in January.

Psychomyidae

45. Polycentropus spp. larvae--10 specimens in 7 collections, all from Camps Canal.

Collections: 70, 72, 74, 76, 80, 82, 91.

Maximum density: .059/plant at #82; 4/m^2 at #74.

Insect associations: Chironomus attenuatus, r=-.873, p=.054, n=5.

All my specimens were collected between May and September at Camps Canal. Katz (1967) recorded this genus from all her collections.

Megaloptera

A total of 17 specimens, all belonging to the same species, were collected. I have found no references for anyone reporting this group from waterhyacinths.

Corydalidae

46. Chauliodes rasticornis Rambur--17 specimens from 10 collections at 2 locations in Alachua Co.

Collections: 11, 42, 69, 70, 72, 73, 74, 89, 91, 95.

Maximum density: .059/plant at #92; 10/m^2 at #69.

Water quality preference: nitrates, r=-.697, p=.055, n=8.

The larvae of this species can be identified by the yellow stripe on the dorsum, as noted by Cuyler (1958). The larvae I collected were correlated with low levels of nitrates in the water. All but one specimen came from Camps Canal.

Coleoptera (Beetles)

With 2,498 specimens (45.5% of the total specimens), the beetles were my most abundant order and were also the best represented, being found in all but 3 of my collections. Collections averaged 33.9 beetles and beetle larvae per collection (excluding the 3 beetle-less collections). At least 64 different species belonging to 42 genera and 10 aquatic families were present. Of the 2,498 beetle specimens, 14.8% were larvae. Most beetle larvae could be identified only to genus except when the genus was monotypic.

O'Hara (1961) reports the following beetles from his waterhyacinth root collection: Dytiscidae, Omophronidae, Haliplidae, Gyrinidae, Carabidae and Hydrophilidae. Carabidae, of which he had only one specimen, are not considered aquatic. Omophronidae, which are considered part of Carabidae by some authorities, have not been reported frequently from Florida and are semi-aquatic, living in the moist soil of riverbanks and lakes. I believe, since these were his most common beetles (and I collected none), that he probably has misidentified a noterid such as Colpius inflatus or a dytiscid such as Hydrovatus sp.

Katz (1967) presents 45 different genera of beetles. At least 10 of her genera, however, belong to families such as Anthicidae, Curculionidae, Scaphidiidae, Scolytidae and Staphylinidae, which are not known to have truly aquatic members in Florida. By truly aquatic, I mean insects which have at least one life stage in or on the water. She also lists

Limnichus sp., which is only known from southwestern U. S., and *Helophorus*, which has not, to my knowledge, been otherwise recorded from Florida.

Dryopidae (Long-Toed Water Beetles)

With only 3 specimens of one species, dryopids were relatively rare in waterhyacinth roots. Since they are usually found in riffle areas of small, rapid streams, few would be expected in the lentic situations in which waterhyacinths are found.

47. *Pelonomus obscurus gracilipes* Chevrolat--3 specimens from 3 collections at Camps Canal, Alachua Co.

Collections: 89, 91, 94.

Maximum density: .091/plant or $5/m^2$ at #94.

Katz (1967) reports collecting *Pelonomus* sp.

Dytiscidae (Predaceous Water Beetles)

With 752 specimens, the dytiscids, along with the Coenagrionidae, were tied for third most abundant family, preceded only by the noterids with 1,432 specimens and the chironomids with 1,046 specimens. At least 30 different species of dytiscids were collected, by far surpassing the 16 species of chironomids, which ranked second in terms of number of species per family. Thus, the contribution of dytiscids to the diversity of the system was very great, especially since they comprised only 13.7% of the total specimens collected and 30.1% of the beetles collected.

Of the dytiscid subfamilies, the Hydroporinae are definitely a characteristic component of waterhyacinth root beetle fauna. The Hydroporinae comprised 89.6% of my dytiscid specimens and of the 12 genera known from Florida, I collected 10.

Of the dytiscid specimens, 132 (17.6%) were larvae. Of the beetle families, only the helodids had more larvae.

Katz (1967) lists the following dytiscid genera from her waterhyacinth root collections: Bidessus, Laccodytes, Hydrovatus, Laccophilus, Orcodytes (=Hydroporus in part?), Celina, Copelatus, Derovatellus, Hygrotus, Coptotomus and Cybister. Of these genera I collected all but Laccodytes, Derovatellus and Hygrotus. O'Hara (1961) found no dytiscid larvae and found adults were relatively rare.

48. Anodochilus exiguus (Aube)--1 specimen collected at Otter Creek, Levy Co., in July.

Collection: 21.

Density: .077/plant.

49. Bidessonotus longavalis (Blatchley)--1 specimen collected at Camps Canal, Alachua Co., in July.

Collection: 18.

50. Bidessonotus pulicarius (Aube)--7 specimens in 5 collections at 2 locations in Alachua Co.

Collections: 36, 75, 93, 94, 95.

Maximum density: .182/plant or 10/m^2 at #94.

Five of my specimens were collected in October while one each were found in June and November.

Bidessonotus spp. females--4 specimens in 4 collections.

Collections: 2, 34, 71, 74.

Maximum density: .026/plant or 5/m^2 at #71.

Since some species of Bidessonotus can be identified only by the shape of the aedeagus, some unidentifiable females of the genera are placed in this classification.

51. Bidessus flavicollis (LeConte)--4 specimens in 2 collections in Alachua and Orange Cos.

Collections: 3, 96.

Maximum density: .15/plant or 15/m^2 at #96.

My specimens were collected in August and November. This species is usually found in algal mats.

52. Brachyvatus seminulus (LeConte)--79 specimens in 10 collections from 6 locations in 2 counties.

Collections: 3, 25, 35, 71, 75, 79, 85, 87, 88, 94.

Maximum density: 1.163/plant or 142.5/m^2 at #85.

Insect associations: Telebasis byersi, r=-.918, p=.028, n=5.

This genus was once considered as a subgenus of Bidessus. A single collection at the Styx River in August accounted for 72% of my specimens of this species, which reached a density of over 140 per square meter. All of my specimens were collected from May through October, with the majority (85%) being collected in August.

53. Celina angustata Aube--6 specimens in 5 collections from 5 locations in 3 counties.

Collections: 15, 19, 29, 77, 79.

Maximum density: .133/plant and $5/m^2$ at #77 and #79.

All my specimens were collected in June or July.

54. *Celina grossula* LeConte--19 specimens in 10 collections from 6 locations in 2 counties.

Collections: 13, 15, 23, 30, 44, 80, 81, 89, 91, 92.

Maximum density: 3.84/plant or $25/m^2$ at #92.

Insect associations: *Colpius inflatus* (LeConte), r=-.934, p=.020, n=5.

This species was significantly negatively correlated with almost all the measures of diversity, indicating that it is generally found in low diversity locations. All my specimens were collected June through September except 2 collected in December in South Florida.

55. *Celina slossoni* Mutchler--3 specimens from 3 locations in Alachua Co.

Collections: 29, 34, 92.

Maximum density: .077/plant or $5/m^2$ at #92.

Collected in July, September and October.

Celina spp. larvae--44 specimens in 22 collections from 9 locations in 2 counties.

Collections: 12, 13, 19, 22, 24, 26, 29, 32, 34, 36, 37, 39, 52, 53, 54, 73, 81, 82, 85, 86, 89, 91.

Maximum density: .333/plant at #37; $15/m^2$ at #86.

Insect associations: *Hydrocanthus* larvae, r=.840, p=.009, n=8; *Polypedilum illinoense* (Malloch), r=.878, p=.021. n=6.

My second most abundant beetle larvae, Celina larvae were found in more different collections than any other beetle larvae.

Celina spp. larvae were collected throughout the year but appear to be most common during late summer and fall. These larvae were found to be strongly associated with a dytiscid larva and significantly associated with a chironomid larva.

56. Copelatus caelatipennis princeps Young--11 specimens in 8 collections from 5 locations in 2 counties.

Collections: 1, 3, 7, 37, 52, 74, 81, 89.

Maximum density: 1.667/plant at #37; 3.33/m^2 at #89.

All my specimens of this species were collected from June through October except for one specimen collected at Lake Alice in February.

57. Copelatus chevrolati chevrolati Aube--13 specimens in 5 collections from 3 locations in 2 counties.

Collections: 1, 21, 42, 93, 94.

Maximum density: .183/plant or 10/m^2 at #94.

Found from July through December, this species is known to prefer areas with accumulations of organic debris.

58. Coptotomus interrogatus obscurus Sharp--3 specimens from 3 locations in 2 counties.

Collections: 17, 27, 103.

Maximum density: .032/plant or 5/m^2 at #103.

Both of my Alachua Co. specimens were collected in July while the one from South Florida was found in December.

59. Cybister frimbiolatus crotchi Wilks.--1 specimen from a drainage ditch in Alachua Co. in February.

Collection: 54.

Density: .036/plant.

While only a single adult of this species was collected, 11 larvae were found. This may indicate that the larvae are most attracted to waterhyacinth roots or perhaps that the adults, among the largest of Florida's water beetles, were able to elude capture.

Cybister sp. larvae--11 specimens in 7 collections from 6 locations in 3 counties.

Collections: 33, 47, 75, 78, 85, 88, 99.

Maximum density: .073/plant or 7.5/m^2 at #75.

Cybister sp. larvae were collected from June through December with most (45.4%) being found in June.

60. Desmopachria grana (LeConte) complex--27 specimens in 16 collections from 11 locations in Alachua Co.

Collections: 1, 11, 14, 15, 19, 23, 27, 34, 37, 39, 41, 52, 57, 91, 94, 95.

Maximum density: .454/plant or 25/m^2 at #94.

Insect associations: Myxosargus sp., $r=.845$, $p=.034$, $n=6$.

This small dytiscid, characteristic of detritus pond conditions, was well-distributed throughout Alachua Co., being present at 11 of the 16 different areas I collected. I collected this species throughout most of the year, with the exception of the spring months. It was most abundant in my October collections, with 38% of the total Desmopachria collected.

61. Hydroporus dixianus Fall--2 specimens collected together at Lake Talquin, Gadsden Co.

Collection: 95.

Density: .1/plant or $10/m^2$.

Only one other specimen of this rare species has been recorded from Florida (Young 1955).

62. Hydroporus lobatus Sharp--11 specimens from 6 collections at 3 locations in Alachua Co.

Collections: 17, 18, 51, 74, 76, 83.

Maximum density: .087/plant at #51; $5/m^2$ at #83.

Of my specimens, 10 were collected during the summer and one in Jaunary. Most (73%) were collected at Camps Canal in Alachua Co.

63. Hydroporus lynceus Sharp--1 specimen collected in November at Lake Talquin, Gadsden Co.

Collection: 96.

Density: .05/plant or $5/m^2$.

64. Hydroporus vittatipennis Gemminger & Von Harold--1 specimen collected in November at Lake Talquin, Gadsden Co.

Collection: 95.

Density: .05/plant or $5/m^2$.

65. Hydrovatus compressus Sharp--276 specimens in 36 collections from 15 locations in 6 counties.

Collections: 12, 23, 24, 25, 26, 29, 30, 32, 33, 36, 37, 39, 41, 44, 46, 49, 52, 55, 57, 71, 75, 76, 78, 79, 80, 81, 83, 84, 85, 86, 88, 89, 91, 92, 93, 97.

Maximum density: 1.095/plant at #49; 110/m^2 at #71.

Water quality preferences: sulphur, r=.785, p=.021, n=8; magnesium, r=.604, p=.010, n=17; sodium, r=.554, p=.021, n=17.

Insect associations: Suphisellus insularis (Sharp), r=.548, p=.006, n=24.

This species was extremely well represented, being found in 41% of my collections. Only one species, the damselfly Ischnura posita, was found in more collections. In sheer numbers, it was my most common dytiscid, my second most abundant beetle, and fifth in abundance out of all the species. Comprising 36.7% of the dytiscids collected, this beetle has significant correlation coefficients indicating that it occurs most commonly in waters that have relatively high values of sulphur, magnesium and sodium. It is negatively correlated with leaves per plant (r=-.486, p=.048, n=17). It is also extremely strongly associated with the presence of the noterid Suphisellus insularis, the only beetle more abundant than H. compressus. If one of these species were present, in 67% of the cases the other would be present also. Lake Alice accounted for 63.6% of the specimens, while Camps Canal provided an additional 17%. This species was abundant especially during late winter and was collected throughout the year.

66. Hydrovatus inexpectatus Young--1 specimen collected in July at Camps Canal, Alachua Co.

Collection: 80.

Density: .013/plant or $1/m^2$.

This species is very similar to _H_. _compressus_ and more specimens may be mixed in with that species. However, Dr. Frank Young, who described the species (Young 1963), examined all my specimens and believes that my determinations are correct.

67. _Hydrovatus_ _peninsularis_ Young--104 specimens in 25 collections from 12 locations in 3 counties.

Collections: 3, 11, 15, 16, 19, 22, 23, 24, 25, 29, 33, 37, 39, 40, 44, 57, 74, 76, 80, 85, 86, 89, 81, 93, 97.

Maximum density: .667/plant at #37; $40/m^2$ at #86.

Insect associations: _Phaenotum_ _exstriatus_ Say, r=.781, p=.013, n=9; _Mesonoterus_ _addendus_ (Blatchley), r=-.837, p=.038, n=6.

Accounting for 14% of the dytiscid specimens, this was my second most abundant and my second best represented species of dytiscid. Strongly associated with taller waterhyacinth plants (r=.447, p=.018, n=24), _H_. _peninsularis_ is also associated with the presence of the hydrophilid _Phaenotum_ _exstriatus_. The conditions which favor the presence of the noterid _Mesonoterus_ _addendus_ would seem to inhibit the presence of _H_. _peninsularis_. _H_. _peninsularis_ appeared to be most abundant in July, during which 30.8% of my specimens were collected.

Hydrovatus sp. larvae--20 specimens in 12 collections from 5 locations in 2 counties.

Collections: 23, 27, 30, 39, 41, 44, 71, 74, 87, 94, 95, 97, 99.

Maximum density: .194/plant at #55; 5/m^2 at #75.

Although *Hydrovatus* larvae are correlated (r=.912, p=.031, n=5) with higher water temperatures, they were found throughout the year.

68. *Laccophilus gentilis* LeConte--17 specimens in 13 collections from 7 locations in 3 counties.

Collections: 23, 27, 30, 39, 41, 44, 71, 74, 87, 94, 95, 97, 99.

Maximum density: .2/plant or 10/m^2 at #97.

Insect associations: *Suphisellus insularis*, r=-.832, p=.040, n=6.

Collected from May through December, over half the specimens were found during the fall. A greater number of leaves per plant was correlated to this species (r=.823, p=.023, n=7).

69. *Laccophilus proximum* Say--14 specimens in 9 collections from 4 locations in 3 counties.

Collections: 38, 45, 75, 91, 92, 94, 95, 101, 102.

Maximum density: .188/plant or 15/m^2 at #102.

Water quality preference: pH, r=.798, p=.031, n=7.

This species seems to prefer waters high in pH. It was collected from June through December.

Laccophilus sp. larvae--4 specimens from 4 locations in Alachua Co.

Collections: 12, 27, 29, 33.

Maximum density: .062/plant or 3.33/m^2 at #88.

All the Laccophilus larvae were collected during the summer months.

70. Liodessus affinis (Say)--2 specimens from 2 locations in 2 counties.

Collections: 18, 48.

Maximum density: .026/plant at #48.

Liodessus was previously considered a subgenus of Bidessus.

71. Liodessus fuscatus (Crotch) -- 1 specimen collected in July at Otter Creek, Levy Co.

Collection: 20.

Density: .306/plant.

This species is usually associated with sphagnum moss.

72. Matus ovatus blatchleyi Leech--1 specimen collected in June at a pond in Alachua Co.

Collection: 11.

Matus sp. larvae--2 specimens collected from 2 locations in Alachua Co. during June and July.

Collections: 11, 23.

Maximum density: .017/plant at #23.

73. Neobidessus pullus floridanus (Fall)--1 specimen from Lake Alice, Alachua Co., in June.

Collection: 75.

Density: .024/plant or $2.5/m^2$.

This genus was also part of the old genus Bidessus.

74. Pachydrus obniger Chevrolat--3 specimens from collections at a drainage ditch in Alachua Co.

Collections: 33, 40.

Maximum density: .038/plant.

Florida specimens of this species were called P. princeps (Blatchley), but Dr. F. N. Young (personal communication) does not believe them to be distinct from the P. obniger from Cuba.

Pachydrus obniger larvae--45 larvae in 18 collections from 8 locations in 3 counties.

Collections: 14, 24, 29, 33, 37, 52, 71, 74, 75, 78, 79, 83, 84, 86, 89, 91, 93, 94.

Maximum density: .469/plant or $25/m^2$ at #89.

Water quality preference: iron, r=.912, p=.031, n=5.

Blatchley (1914) recorded this species (as P. princeps, a new species) from beneath dead waterhyacinths along the shore of Lake Okeechobee.

Insect associations: Hydrovatus peninsularis, r=.681, p=.043, n=9; Phaenotum exstriatus, r=.875, p=.010, n=7; Suphisellus gibbulus (Aube), r=.744, p=.021, n=9; Myxosargus sp., r=.889, p=.017, n=6.

Pachydrus larvae were found in waters having high iron content and frequently having populations of the dytiscid H. peninsularis, the hydrophilid P. exstriatus, the noterid S. gibbulus, and the stratiomyid Myxosargus. Over 55% of the specimens came from Camps Canal, and all but 2 specimens were collected between May and October.

75. Thermonectus basillaris (Harris)--1 specimen collected in July at a drainage ditch in Alachua Co.

Collection: 22.

Density: .055/plant.

76. Uvarus falli (Young)--1 specimen collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .077/plant.

This species is thought to be restricted to sand-bottomed streams such as Otter Creek.

Unidentifiable Bidessini larvae--10 larvae in 7 collections from 4 locations in Alachua Co.

Collections: 19, 24, 25, 49, 52, 86, 91.

Maximum density: .143/plant at #49; 5/m^2 at #86.

Some dytiscid larvae could be identified only to the tribe level. The tribe Bidessini has 5 genera: Bidessus (sensu latu), Bidessonotus, Brachyvatus, Desmopachria and Pachydrus.

Elmidae (Riffle Beetles)

It is not surprising that I collected only 3 specimens from this family since its members are usually restricted to riffle areas of streams. Katz (1967) found 3 genera of elmids in her waterhyacinth root collections.

77. Dubiraphia quadrinotata (Say)--3 specimens in 2 collections from 2 counties.

Collections: 18, 103.

Maximum density: .032/plant or 5/m^2 at #103.

Gyrinidae (Whirligig Beetles)

Only 3 specimens from 3 different species were collected from waterhyacinth roots. While members of this family were frequently present at the collecting site, they seem to prefer patches of open water larger than that found between waterhyacinth plants in a mat. O'Hara (1961) reports collecting gyrinid larvae but no adults. Katz (1967) records one genus of gyrinid but does not distinguish whether larvae or adults or both were found.

78. *Dineutes* sp. larvae--1 specimen at Otter Creek, Levy Co., in July.

Collection: 21.

Density: .077/plant.

Katz (1967) reports this genus from several of her collections.

79. *Gyrinus elevatus* LeConte--single specimen collected at Peace River, Hardee Co., in December.

Collection: 102.

Density: .063/plant or $5/m^2$.

80. *Gyrinus woodruffi* Fall--single specimen collected in October at Camps Canal, Alachua Co.

Collection: 35.

Density: .031/plant.

This species is considered to be primarily a stream species, thus it would not be expected in the lentic habitats that waterhyacinths prefer.

Haliplidae (Crawling Water Beetles)

Only 12 specimens in 3 different species in one genus were found. While not common, they were not truly rare in waterhyacinth roots. Since adults crawl and swim along the bottom, they probably only occasionally hide in waterhyacinth roots. Katz (1967) recorded *Peltodytes* sp. from 2 of her collections. O'Hara (1968) found haliplids locally abundant but recorded only the genus *Haliplus*, which was not collected either by Katz or myself.

81. *Peltodytes dietrichi* Young--3 specimens in a single collection in July from Otter Creek, Levy Co.

Collection: 21.

Density: .231/plant.

This recently described species (Young 1961) was collected only once.

82. *Peltodytes floridensis* Matheson--6 specimens from 3 collections at 2 locations in 2 counties.

Collections: 20, 21, 87.

Maximum density: .385/plant at #21; 2.5/m^2 at #87.

83. *Peltodytes oppositus* Roberts--3 specimens from 3 locations in 2 counties.

Collections: 38, 71, 102.

Maximum density: .063/plant or 5/m^2 at #102.

Helodidae (=Cyphonidae) (Marsh Beetles) Larvae

The Helodidae, sometimes also known as the Cyphonidae, consisted of 138 larvae belonging to 2 genera and at least

3 species. In older literature, usually considered a part of Dascillidae, the American helodid fauna is very poorly known, with the best key to the species of adults being almost 100 years old (Horn 1880). Existing keys to larvae, such as Leech and Chandler (1968), do not include all the genera. My specimens were identified by rearing the larvae and comparing the adults to old species descriptions and identified material at The Florida State Collection of Arthropods. While the adults enter the water only for oviposition or escape, the larvae were sometimes abundant in closely packed, detritus-filled mats of waterhyacinths. Katz (1967) collected specimens from this family but reports _Cyphon_, a genus which I did not find, and does not mention the genera I collected.

84. _Ora hyacintha_ Blatchley (adults reared from larvae)--3 specimens reared from larvae from 2 collections at a drainage ditch, Alachua Co.

Collections: 33, 37.

Maximum density: .333/plant.

Described by Blatchley in 1914 from adults found among dead waterhyacinths on the shore, this species could be distinguished from my other species of _Ora_ only in the adult stage. The species name seems especially appropriate in view of the abundance of what are probably larvae of this species in some waterhyacinth habitats.

85. _Ora troberti_ (Guer.) (adults reared from larvae)--3 specimens from 2 locations at a drainage ditch in Alachua Co.

Collections: 33, 37.

Maximum density: .333/plant.

The adults of this species were also obtained from rearing collected larvae. While my specimens appear to fit the description for this species, they may represent another similar, yet undescribed species.

Ora sp. larvae--90 specimens from 8 collections at a drainage ditch in Alachua Co.

Collections: 22, 33, 37, 40, 43, 51, 54, 57.

Maximum density: .879/plant.

I could not distinguish the larvae of *O. hyacintha* from the larvae of *O. troberti* due to the overlap of almost all characteristics studied. All *Ora* larvae were lumped together; even though the largest larvae were almost surely *O. hyacintha*, the smaller larvae could be either species. *Ora* sp. larvae were associated with waterhyacinths growing in deeper water. All my *Ora* larvae came from the same location, a drainage ditch off of I-75 north of Micanopy in Alachua Co., where they were the most frequently collected and second most numerous insects found. All but 10 specimens were collected in the fall and early winter months.

86. *Scirtes* spp. adults--single specimen from drainage ditch in Alachua Co. in September.

Collection: 33.

Density: .019/plant.

A single *Scirtes* adult was found. Although adults are not truly aquatic, since they sometimes enter the water this specimen was not excluded from my collection.

Scirtes sp. larvae--41 specimens from 13 collections in 9 locations in 2 counties.

Collections: 11, 12, 13, 14, 51, 22, 33, 51, 54, 75, 89, 90, 97.

Maximum density: .545/plant or $30/m^2$ at #90.

Insect associations: *Telebasis byersi*, $r=-.886$, $p=.045$, $n=5$.

Scirtes larvae were found at many more different locations than *Ora* larvae although not as many specimens were collected. Unlike the *Ora* larvae, most were collected during the summer, although some were found during the winter also. *Scirtes* larvae also appear to be associated with waterhyacinths plants having shorter roots.

Hydraenidae (=Limnebiidae) (Minute Moss Beetles)

These tiny beetles, less than 1¼ mm long, were never abundant in my collections, and their size may have contributed to their being overlooked in some collections. Only one of the two species known from Florida was found and it was represented by 12 specimens. Neither O'Hara (1961) nor Katz (1967) records any members of this family.

87. *Hydraena marginicollis* Kiesenwetter--12 specimens from 7 collections at 5 locations in 2 counties.

Collections: 2, 3, 21, 33, 34, 42, 53.

Maximum density: .154/plant.

Hydrochidae

Considered by many to be a subfamily of the hydrophilids, I felt that Drs. Young, Hellman and others were justified in considering the hydrochids a separate family. Only 9 specimens belonging to 4 different species were collected. All were identified by Dr. Hellman of the University of Maryland.

88. *Hydrochus inaequalis* LeConte--5 specimens from 4 collections at Camps Canal, Alachua Co.

Collections: 38, 53, 91, 94.

Maximum density: .091/plant or 5/m^2 at #94.

89. *Hydrochus prolatus* Hellman--single specimen collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .077/plant.

90. *Hydrochus simplex* LeConte--single specimen collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .077/plant.

91. *Hydrochus woodi* Hellman--2 specimens in 1 collection from Camps Canal in July.

Collection: 17.

Density: .061/plant.

Hydrophilidae (Water Scavenger Beetles)

With only 131 specimens, 17 of which were larvae, hydrophilids were not one of my most abundant families. While only 3 of the 13 species were represented by 10 or more individuals, they were fairly well distributed, with hydrophilids being found in 40 collections. O'Hara (1961) reports collecting no larvae and that hydrophilid adults were rare. Of the Hydrophilidae genera listed by Katz (1967) from waterhyacinth roots, I collected: *Paracymus*, *Enochrus*, *Tropisternus*, *Phaenotum*, *Berosus*, *Helobata*, *Helochares* and *Crenitulus*. I additionally collected *Cercyon*, *Derrallus* and *Hydrobiomorpha*, while she also found *Helophorus* and *Laccobius*.

92. *Berosus exiguus* Say--2 specimens collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .154/plant.

This species is usually collected from sand-bottomed streams such as Otter Creek.

93. *Cercyon praetextatus* Say--single specimen collected in May at Camps Canal, Alachua Co.

Collection: 73.

Density: .008/plant or $1/m^2$.

94. *Crenitulus suturalis* (LeConte)--18 adults from 4 collections at 3 locations in 2 counties.

Collections: 1, 21, 22, 33.

Maximum density: .225/plant.

This was my third most numerous hydrophilid, but two-thirds of my specimens were in collection #33, with the I-75 drainage ditch supplying 78% of the specimens. All were collected from June through July.

Crenitulus suturalis (?) larvae--1 larva collected in August at Camps Canal, Alachua Co.

Collection: 89.

Density: .031/plant or $1.66/m^2$.

This larva is different from any of the described genera from Florida. Since Crenitulus, a monotypic genus, is the only known genus of hydrophilid from Florida and whose larva is not known, Dr. Paul Spangler at the Smithsonian believes it highly probable that the larva is of Crenitulus suturalis.

95. Derrallus altus (LeConte) adults--6 specimens in 5 collections from 2 locations in 2 counties.

Collections: 17, 72, 79, 91, 94.

Maximum density: .182/plant or 10/m^2 at #94.

Derrallus altus larvae--3 specimens in 3 collections from 2 locations in Alachua Co.

Collections: 49, 50, 70.

Maximum density: .048/plant at #49; 1.67/m^2 at #70.

96. Enochrus blatchleyi (Fall)--2 specimens in 2 collections from a drainage ditch in Alachua Co.

Collections: 40, 51.

Maximum density: .043/plant at #51.

97. Enochrus ochraceus Melsheimer--29 specimens in 16 collections from 6 locations in 3 counties.

Collections: 3, 18, 30, 33, 41, 42, 43, 45, 70, 71, 86, 89, 91, 94, 95, 98.

Maximum density: .353/plant or 30/m^2 at #70.

This species, a detritus pond inhabitant, was my second most abundant hydrophilid and was tied in the number of collections in which it was found. All my specimens were collected between May and December, with over half coming from Camps Canal.

98. Enochrus perplexus (LeConte)--4 specimens from 2 collections at 2 locations in Alachua Co.

Collections: 16, 94.

Maximum density: .273/plant or 15/m^2 at #94.

Enochrus sp. larvae--5 specimens from 4 collections at 3 locations in 2 counties.

Collections: 15, 30, 51, 79.

Maximum density: .087/plant at #51; 5/m^2 at #79.

99. Helobata striata (Brulle)--2 specimens in 2 collections at 2 locations in Alachua Co.

Collections: 3. 34.

Maximum density: .04/plant.

Blatchley (1932) has recorded this species from leaves of pickerelweed, Pontederia, as has Young (1954). These flattened insects stick limpet-like to submerged objects. This type of behavior may cause them to appear more rare than they really are, since they might be difficult to dislodge by mere washing of waterhyacinth roots.

100. Helochares sp. larvae--1 specimen collected in June at a small pond in Hardee Co.

Collection: 78.

Density: .013/plant; 1.67/m^2.

101. Hydrobiomorpha casta (Say) adults--7 specimens in 4 collections at 3 locations in Alachua Co.

Collections: 30, 71, 94, 95.

Maximum density: .273/plant or 15/m^2 at #94.

This genus is frequently referred to as Neohydrophilus. These fairly large insects were never very common in my collections. However, this species is positively correlated with several measures of diversity, indicating that it is found in high diversity situations.

Hydrobiomorpha casta larvae--2 specimens from 2 collections at 2 locations in Alachua Co.

Collections: 24, 89.

Maximum density: .031/plant or 1.67/m^2 at #89.

102. Paracymus despectus (LeConte)--single specimen collected in December at a roadside canal in Palm Beach Co.

Collection: 46.

Density: .043/plant.

103. Phaenotum exstriatus (Say)--33 specimens in 16 collections from 5 locations in 2 counties.

Collections: 3. 11, 15, 17, 22, 31, 35, 37, 69, 79, 86, 89, 91, 93, 94, 95.

Maximum density: .20/plant at #95; 40/m^2 at #79.

Insect associations: Hydrovatus peninsularis, r=.781, p=.013, n=9; Pachydrus larvae, r=.875, p=.010, n=7.

This species, a member of the subfamily Sphaeridinae whose members are generally not considered aquatic, was my most numberous hydrophilid and tied for being represented in the most collections. It constituted over 25% of the hydrophilids collected. This species is strongly correlated with the presence of two dytiscids, Hydrovatus peninsularis and the larvae of Pachydrus. Over 60% of my specimens were collected at Camps Canal and all were collected from mid-June through early November. This would coincide with the build-up of detritus as waterhyacinth mats senesced.

104. Tropisternus blatchleyii D'Orchymont--8 specimens from 3 collections at Camps Canal, Alachua Co.

Collections: 3, 18, 74.

Maximum density: .008/plant or $1/m^2$ at #74.

Tropisternus sp. larvae--6 specimens in 3 collections from 2 locations in Alachua Co.

Collections: 22, 89, 90.

Maximum density: .22/plant at #22; $5/m^2$ at #90.

Noteridae (Burrowing Water Beetles)

With 1,432 specimens, 82 of which were larvae, the noterids were easily my most abundant insect family and can be considered as a characteristic component of waterhyacinth fauna. Comprising 57.3% of all the beetles collected and over 26% of all the insects collected, this family was represented in 84% of my collections, with as many as 174 noterids being found in a single collection. Of the 10 (or 11, the status of Suphisellus punctipennis (Sharp) being questionable) species of noterids known to occur in Florida, I collected 8, all except Notomicrus manulus (LeConte) and Suphisellus parsoni Young, of which the two types are the only known specimens. Such relatively rare species as Mesonoterus addendus (Blatchley) were fairly common in waterhyacinth roots and the 4 specimens of Pronoterus semipunctatus (LeConte) which I found more than doubled the known specimens for the state.

O'Hara (1961) amazingly does not report any members of this family, but I believe that he may have misidentified them as Omophronidae. Katz (1967) records all the genera that I collected if her Pronoterus includes what is now called Mesonoterus.

105. Colpius inflatus (LeConte) adults--177 specimens in 23 collections from 6 locations in 4 counties.

Collections: 3, 18, 22, 31, 33, 43, 44, 50, 71, 72, 73, 74, 81, 84, 89, 91, 92, 93, 94, 95, 97, 99, 102.

Maximum density: 4.6/plant or 230/m^2 at #97.

Insect associations: Celina grossula, r=-.934, p=.020, n=5.

Dr. Paul Spangler at the National Museum believes this species to be a member of the tropical genus Suphis. This species was my fourth most abundant beetle and ranked as my seventh most abundant species overall. They sometimes reached very high densities, such as 230 specimens per square meter of waterhyacinth mat at a roadside ditch in Liberty Co. They appear to be common throughout the year.

Over 59.3% of my specimens came from Camps Canal.

Colpius inflatus larvae--15 specimens in 5 collections from 3 locations in 2 counties.

Collections: 21, 41, 55, 75, 80.

Maximum density: .154/plant at #21; 12.5/m^2 at #75.

The most distinctive larvae of a nondescript group, they were collected in mid-summer and early winter.

106. *Hydrocanthus oblongus* Sharp--60 specimens in 26 collections from 14 locations in 6 counties.

Collections: 1, 3, 11, 12, 18, 22, 25, 31, 34, 35, 38, 45, 57, 70, 78, 79, 87, 89, 91, 93, 94, 95, 97, 99, 102, 103.

Maximum density: 1.00/plant at #45; $20/m^2$ at #95.

Insect associations: *Caenis diminuta*, r=.841, p=.002, n=10; *Enallagma signatum-pollutum* complex, r=.655, p=.040, n=10.

H. oblongus did not appear to be quite as abundant as *H. regius* but seemed to be more widely distributed, being collected at more locations. All but 3 of my specimens were collected from late June through December. *H. oblongus* seemed very sensitive, significant at the 0.2% level, to the population levels of the mayfly *Caenis diminuta*.

107. *Hydrocanthus regius* Young--104 specimens from 36 collections at 8 locations in 3 counties.

Collections: 2, 11, 17, 18, 24, 25, 32, 35, 36, 38, 41, 49, 55, 56, 70, 71, 72, 73, 74, 76, 78, 80, 81, 84, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 97, 99.

Maximum density: 1.545/plant or $85/m^2$ at #94.

Water quality preference: hardness, r=-.476, p=.025, n=22; nitrates, 4=.423, p=.050, n=22; magnesium, r=.563, p=.006, n=22.

This species was found to significantly prefer cool water that was low in hardness and magnesium but which was high in nitrates. They were common throughout the year but seemed to become more abundant at Camps Canal during mid fall. This was my fifth most abundant beetle species and was tied for second in number of collections in which it was found.

Hydrocanthus sp. larvae--24 specimens in 12 collections from 8 locations in 3 counties.

Collections: 1, 23, 26, 52, 73, 79, 81, 82, 86, 86, 87, 91.

Maximum density: .176/plant or 15/m^2 at #86.

Insect associations: *Celina* larvae, r=.840, p=.009, n=8.

These were my second most abundant noterid larvae and were very significantly associated with the presence of *Celina* larvae. While one *Hydrocanthus* larva was collected in February, all the rest were found between late May and mid-September.

108. *Mesonoterus addendus* (Blatchley)--70 specimens in 15 collections from 5 locations in 3 counties.

Collections: 24, 29, 32, 36, 39, 41, 44, 49, 52, 71, 75, 88, 89, 92, 97.

Maximum density: .762/plant at #49; 10/m^2 at #71, #88, #97.

Water quality preference: alkalinity, r=.831, p=.040, n=6; hardness, r=.815, p=.048, n=6; conductivity, r=.836, p=.038, n=6.

Insect associations: *Hydrovatus peninsularis*, r=-.837, p=.038, n=6.

This species was previously considered as *Pronoterus addendus*, but Dr. Young (personal communication) believes it closer to *Mesonoterus*. Members of this species appear to prefer waters that are alkaline and are high in hardness and conductivity which, perhaps, are less productive, since there are negative correlations between this species and some indices of diversity. This species seems to be definitely associated with waterhyacinths (Young 1954). Young, in his study, collected only 2 specimens and none from Alachua Co. Of my specimens, 65 came from Alachua Co., with over 95% of these coming from Lake Alice, where Young frequently collected. This is additional evidence for the close relationship of this species to waterhyacinths, since Lake Alice did not become infested with waterhyacinths until the mid 1960's (Cason 1970). Collected throughout the year, this species appeared to be more abundant in late fall and early winter.

109. *Pronoterus semipunctatus* (LeConte) adults--4 specimens from 3 locations in Alachua Co.

Collections: 29, 34, 37.

Maximum density: .167/plant at #37.

As of 1954 only 3 specimens of this relatively rare species had been recorded from Florida and none from Alachua Co. My specimens were collected in July or October.

Mesonoterus or *Pronoterus* (?) sp. larvae--7 specimens in 4 collections at 4 locations in 2 counties.

Collections: 13, 24, 26, 33.

Maximum density: .061/plant at #24.

Since only 2 genera of noterid larvae are definitely known, Colpius (=Suphis) and Hydrocanthus, these larvae were identified by means of eliminating the known genera and comparing the remaining larval types with the relative abundances of the adults.

110. Suphisellus gibbulus (Aube)--332 specimens from 36 collections at 19 locations in 10 counties.

Collections: 1, 11, 18, 19, 22, 25, 26, 27, 29, 30, 33, 37, 40, 43, 44, 45, 47, 48, 54, 57, 76, 79, 80, 81, 83, 86, 87, 89, 91, 93, 94, 95, 97, 101, 102, 103.

Maximum density: 3.83/plant at #37; 40/m^2 at #83.

Water quality preference: chlorides, r=-.504, p=.056, n=15.

This was my second most abundant beetle species (third in overall abundance) and was tied with Hydrovatus compressus and Suphisellus insularis for second overall in the number of collections in which it was present. Populations at the I-75 drainage ditch north of Micanopy were especially heavy, with only 2 of my 7 collections from there having less than 20 specimens. This location accounted for over 70% of all specimens of this species. Young (1954) reports of this species: "One of its favorite haunts is among the roots of water hyacinths floating in shallow water" (p. 132). My analyses have revealed an extremely strong negative correlation (r=-.611, p=.0001, n=34) with root length. These beetles definitely prefer waterhyacinth plants with short roots. As noted in the introduction, root length appears to be inversely related to the nutrient content of the water, although I found no correlations between this species and some of the common nutrients such as nitrates and phosphates. There were also significant correlations with low levels of magnesium and increasing depth of water. I have collected this species throughout the year except the spring months.

111. *Suphisellus insularis* (Sharp)--549 specimens in 33 collections at 14 locations in 6 counties.

Collections: 2, 3, 4, 11, 13, 19, 24, 25, 26, 29, 30, 32, 36, 39, 41, 44, 47, 49, 52, 55, 56, 71, 75, 78, 79, 80, 85, 86, 88, 89, 91, 93, 94.

Maximum density: 3.68/plant or 337.5/m^2 at #75.

Water quality preference: potassium, r=.599, p=.039, n=12.

Insect associations: *Pelocoris balius*, r=-.549, p=.052, n=13; *Hydrovatus compressus*, r=-.832, p=.040, n=6; *Hydrocanthus* sp. larvae, r=-.850, p=.032, n=6.

This was my most abundant beetle species and only a chironomid exceeded it in total numbers. However, 3 other beetles exceeded it in the number of collections in which they were present. It sometimes reached incredible densities, such as 377.5 per square meter at Lake Alice. The populations at Lake Alice were consistently heavy, with only 2 of my 12 collections there having less than 10 *S. insularis* and with this location accounting for 76.5% of the total specimens of this species. This species preferred deeper waters which were high in potassium. *S. insularis* had a very strong (r=-.464, p=.006, n=33) negative correlation with Simpson's diversity index and could therefore be considered an indicator of low diversity conditions. It was also negatively correlated with *Pelocoris balius*, *Laccophilus gentilis*, and the larvae of *Hydrocanthus*. However, it was very strongly correlated (0.6% level) with the population levels of *Hydrovatus compressus*, my second most abundant beetle species. This species appears to be abundant throughout the year.

112. *Suphisellus puncticollis* Crotch--44 specimens in 18 collections from 10 locations in 3 counties.

Collections: 1, 7, 15, 22, 27, 29, 34, 37, 40, 43, 44, 57, 71, 76, 86, 89, 91, 93.

Maximum density: 1.5/plant at #37; 10/m^2 at #86.

Water quality preference: potassium, r=.826, p=.043, n=6.

This species was never particularly abundant, with 9 specimens being the most in any one collection. The I-75 drainage ditch accounted for 21 of the specimens. *S. puncticollis* was collected throughout most of the year.

Suphisellus (?) sp. larvae--43 specimens in 12 collections from 9 locations in 2 counties.

Collections: 12, 19, 22, 23, 26, 29, 32, 36, 75, 83, 88, 89.

Maximum density: .390/plant or 40/m^2 at #75.

Suphisellus larvae were my most abundant noterid larvae and were collected between mid-June and mid-October.

Unidentified noterid larvae--3 specimens in November from Lake Alice, Alachua Co.

Collection: 39.

Density: .143/plant.

These 3 larvae were in too poor condition to be identified following unsuccessful rearing attempts.

Lepidoptera (Moths)--Larvae

With only 13 specimens from 10 collections, the larvae of aquatic Lepidoptera were never abundant and comprised only 0.2% of the total specimens I collected. O'Hara (1961) did not collect any Leipdoptera larvae. Katz (1968) reports finding the genera *Elophila* and *Nymphula*. Dr. D. H. Habeck (personal communication) feels that these are misidentifications, with *Nymphula* probably being *Synclita obliteralis* (Walker).

Pyralidae

113. *Neargyractis slossonalis* (Dyar) larvae--2 specimens from 2 locations in Alachua Co.

Collections: 13, 24.

Density: .030/plant at #24.

The larvae of this uncommon species have been previously reported only from root hairs of trees growing along banks of rivers and streams (Habeck, unpublished). My specimens were collected in June and July.

114. Synclita obliteralis (Walker) larvae--11 specimens in 8 collections from 3 locations in Alachua Co.

Collections: 43, 51, 54, 70, 72, 73, 75, 94.

Maximum density: .310/plant at #51.

The floating larval cases, usually made from 2 pieces chewed from a waterhyacinth leaf, were often numerous on the water surface around waterhyacinth plants, but only those cases recovered after washing the waterhyacinth roots were collected. S. obliteralis larvae were found sporadically throughout the year.

Diptera (Flies)--Larvae and Pupae

Represented in 69 collections, the Diptera, with 1,265 specimens, constituted my second most abundant order. Only 33 species in 11 families were present, as compared to the 64 species in 10 families of aquatic Coleoptera. The chironomids, with 1,046 specimens, were by far the most abundant Diptera and constituted 82.7% of the Diptera and 19.1% of all insects collected. Both O'Hara (1961) and Katz (1967) found chironomids to be their most abundant insect group. Only 2 other Diptera families, the Culicidae and Stratiomyidae, were represented in my collections by more than 9 specimens.

Ceratopogonidae (Biting Midges)

These tiny, almost translucent larvae, were probably frequently overlooked and their relative numbers are probably much higher than the number of specimens in my collection. O'Hara (1961) reports collecting members of this family while Katz (1967) records the genera Bezzia and Culicoides from her collections. Since pupae cannot be keyed and less than half of Florida's 22 genera are present in most larval keys, I did not key out my ceratopogonid larvae and pupae.

115. Unidentified ceratopogonid larvae and pupae--9 specimens in 8 collections at 4 locations in 2 counties.

Collections: 1, 15, 53, 70, 74, 76. 78, 89.

Maximum density: .031/plant at #89; 3.33/m^2 at #78.

Water quality preference: hardness, r=.973, p=.005, n=5; magnesium, 4=.994, p=.0005, n=5; sodium, r=.940, p=.018, n=5; conductivity, r=.974, p=.005, n=4.

One ceratopogonid larva was collected in February while the rest were found between May and August. The larvae came from water high in sodium and magnesium and had high hardness and conductivity.

Chaoboridae (Phantom Midges)

116. Corethrella prob. bradleyi (Coquillet)--5 specimens in 3 collections from 3 locations in Alachua Co.

Collections: 24, 34, 89.

Maximum density: .12/plant at #34.

These small mosquito-like larvae were not common. Katz (1967) reports them from one of her collections.

Chironomidae (Midges) Larvae

Found in over half of my collections, chironomids, with 1,046 specimens, were my most abundant Diptera family, comprising 82.7% of all Diptera collected, and only the noterids as a family had more specimens. Of my 15 species of chironomids, a single species, *Chironomus attenuatus* Walker, accounted for 72.6% of my specimens. O'Hara (1961) found chironomids to be ". . . by far the most abundant insect larvae in the hyacinth community" (p. 43). His results may be biased since he collected exclusively from canals in South Florida. I found that chironomid larvae were especially dense in canals such as Camps Canal. He did not go beyond family level in his determinations. Katz (1967) also reports chironomids as her most abundant insect family and lists 12 genera, of which only 3, *Harnischia*, *Polypedilum*-*Phaenospectra* complex, and *Tendipes* (=*Chironomus*), are represented among the 12 genera I collected. Since she used the rather incomplete keys in Pennak (1953), I believe some of her determinations to be questionable. My specimens were all identified by Mr. W. M. Beck, renowned chironomid specialist at Florida A & M.

117. *Ablabesmyia janata* (Roback)--10 specimens from 4 collections at Camps Canal in Alachua Co.

Collections: 74, 76, 82, 86.

Maximum density: .353/plant or 30/m^2 at #82.

The larvae of this species were collected only in June and August.

118. Ablabesmyia peleensis (Walley)--8 specimens in 5 collections from 2 locations in Alachua Co.

Collections: 29, 31, 69, 74, 76.

Maximum density: 5 larvae/m^2 at #69.

These larvae were collected between April and September.

Ablabesmyia sp. larva--1 specimen from a stream in Charlotte Co.

Collection: 79.

Density: .009/plant or 5/m^2.

This larva was too small to identify to species.

119. Chironomus attenuatus Walker larvae--760 specimens in 25 collections at 8 locations in 4 counties.

Collections: 18, 22, 27, 34, 39, 41, 46, 49, 52, 54, 55, 71, 74, 76, 77, 79, 80, 81, 82, 84, 86, 89, 91, 92, 93.

Maximum density: 6.1/plant or 580/m^2 at #77.

Water quality preference: temperature, r=.570, p=.053, n=12.

Insect associations: Belostoma sp. nymphs, r=-.661, p=.053, n=9; Polycentropus sp. larvae, r=-.873, p=.054, n=5; Pachydrus obniger larvae, r=.774, p=.021, n=0.

This was my most abundant species of insect and it was frequently very abundant, with an average density of 129.4 larvae per square meter, whenever it was collected. The maximum density of 580/m^2 is almost twice that observed for any other species. This single species comprised 72.6% of all the chironomids collected and 13.8% of all the insects found and exceeded the number of specimens in the Coenagrionidae or the Dytiscidae, two of my most abundant families. The larvae live in tubes of silt and algae attached to the roots and submerged portions of waterhyacinths.

120. Dicrotendipes leucoscelis (Townes)--single specimen collected at Camps Canal, Alachua Co., in October.

Collection: 35.

Density: .031/plant.

121. Dicrotendipes lobus Beck--single specimen collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .077/plant.

122. Endochironomus nigricans Johannsen--2 specimens from 2 counties.

Collections: 71, 100.

Maximum density: .048/plant or 5/m^2 at #100.

123. Glyptotendipes lobiferus Say--single specimen collected in June at Camps Canal, Alachua Co.

Collection: 76.

Density: .009/plant or .588/m^2.

124. Goeldichironomus holoprasinus (Goeldi)--18 specimens in 6 collections at 4 locations in 4 counties.

Collections: 26, 33, 37, 43, 46, 78.

Maximum density: .39/plant at #46.

125. Harnischia sp.--2 specimens from 2 collections at Camps Canal, Alachua Co.

Collections: 76, 82.

Maximum density: .059/plant or 5/m^2 at #82.

126. Larsia sp.--6 specimens in 2 collections from Camps Canal in Alachua Co.

Collections: 76, 80.

Maximum density: .043/plant or 2.94/m^2 at #26.

These larvae were collected in late June and early August.

127. Parachironomus hirtalatus (Beck & Beck)--1 specimen collected in July at Otter Creek, Levy Co.

Collection: 21.

Density: .077/plant.

128. Parachironomus pectinatellae (Dendy & Sublette)--1 specimen collected in November at Lake Talquin, Gadsden Co.

Collection: 96.

Density: .05/plant or 5/m^2.

Parachironomus sp. larvae--68 specimens in 4 collections at 2 locations in 2 counties.

Collections: 74, 80, 81, 96.

Maximum density: .80/plant or 64/m^2 at #80.

Of these larvae, which were too small to be identified to species, 94% were from a single collection at Camps Canal.

129. Phaenospectra sp.--3 specimens in 3 collections from 2 locations in 2 counties.

Collections: 31, 48, 53.

Maximum density: .030/plant at #53.

130. Polypedilum fallax (Johannsen)--1 specimen collected in November at Lake Talquin, Gadsden Co.

Collection: 96.

Density: .05/plant or 5/m^2.

131. Polypedilum illinoense (Malloch)--156 specimens in 13 collections from 5 locations in 2 counties.

Collections: 29, 34, 37, 43, 50, 53, 54, 57, 74, 76, 80, 91, 96.

Maximum density: 1.56/plant or 125/m^2 at #80.

Insect associations: Celina sp. larvae, $r=.878$, $p=.021$, $n=6$.

This was my second most abundant species of chironomid and was my eighth most abundant overall. 125 larvae of this species were collected in July at Camps Canal, where 88.5% of the specimens were collected. While more were found in the springtime, this species appeared irregularly throughout the year.

Polypedilum sp. larvae--2 larvae in 2 collections in Alachua Co.

Collections: 40, 51.

Maximum density: .037/plant at #50.

Culicidae (Mosquitoes) Larvae and Pupae

While mosquitoes are about the only group of aquatic insects whose presence beneath waterhyacinths has received any attention, I did not find them particularly abundant, with 19 collections having 82 specimens in 5 genera and 6 species. O'Hara (1961) did not report any from his collections in canals in South Florida. Barber and Hayne (1925) reported 4 species of Anopheles found among waterhyacinths in the southern states. They found *A. crucians* Wiedemann to be the most widely distributed and commonly collected species but noted that *A. quadrimaculatus* Say, my most common anopheline, was the most common mosquito in some waterhyacinth-infested lakes in Florida. My most common mosquito larva, *Coquillettidia perturbans* (Walker), previously classified as part of the genus *Mansonia*, is considered by Mulrennan (1962) and by Seabrook (1962) to be the most common and important mosquito species breeding in waterhyacinths in Florida. They also mention *A. crucians* and *A. quadrimaculatus*, both species of *Mansonia*, and various *Culex* species as being of lesser importance. Katz (1967) found 3 genera of mosquito larvae: *Orthopodomyia*, *Mansonia* (including what is now *Coquellettidia perturbans*) and *Uranotaenia*. She collected no anophelines and amazingly her most commonly collected species was *Orthopodomyia signifera* (Coquillett), almost certainly a misidentification since this species is almost strictly a tree-hole breeder, occasionally also being found in artificial containers.

132. *Anopheles crucians* Wiedemann larvae--1 larva collected in August at Camps Canal, Alachua Co.

Collection: 86.

Density: .059/plant or 5/m^2 at #86.

This was considered by Barber and Hayne (1925) to be the most common waterhyacinth-breeding mosquito in the southern U.S.A. Both Mulrennan (1962) and Seabrook (1962) consider this one of the more common species among Florida waterhyacinths.

133. Anopheles quadrimaculatus Say--21 specimens in 7 collections from 3 locations in 2 counties.

Collections: 3, 21, 42, 48, 50, 53, 89.

Maximum density: .260/plant at #50.

The larvae of this malarial vector were fairly frequent in situations where the waterhyacinth mat was not too dense but they were never very abundant. Barber and Hayne (1925), Mulrennan (1962) and Seabrook (1962) all consider this a common waterhyacinth culicid.

134. Coquillettidia perturbans (Walker)--24 specimens in 6 collections from 5 locations in Alachua Co.

Collections: 11, 12, 14, 16, 24, 34.

Maximum density: .214/plant at #16.

The larvae of this species, like other members of the genus Mansonia of which it was formerly considered a member, attach themselves to submerged portions of aquatic plants by their modified siphon and obtain their oxygen directly from the plant. Since they readily drop off the plant when disturbed, their frequencies beneath waterhyacinths are much higher than indicated by the number of specimens in my collection. This species is probably the Mansonia reported by Katz (1967) and considered the most important waterhyacinth-breeding mosquito species in Florida by both Mulrennan (1962) and Seabrook (1962). This species was negatively correlated with most diversity indices.

135. Culex territans Walker--24 larvae and pupae collected in July at a drainage ditch in Alachua Co.

Collection: 22.

Density: 1.33/plant.

A permanent pool species, the larvae are not usually found in foul water such as waterhyacinths grow in.

136. Mansonia titillans (Walker)--3 larvae collected in September at a roadside canal in Indian River Co.

Collection: 6.

These were the only insects at this location, which had a layer of oil on top of the water, probably washed in from the adjacent Florida Turnpike.

137. Uranotaenia sapphirina (Osten Sacker)--9 specimens in 4 collections from 4 locations in Alachua Co.

Collections: 34, 37, 86, 88.

Maximum density: .167/plant at #37; 15/m^2 at #85.

The larvae of this species prefer lakes and ponds with floating or emergent vegetation and are "commonly associated with Anopheles quadrimaculatus Say" (Carpenter and LaCasse 1955). However, only Katz (1967) mentions the genus as being found among waterhyacinths.

Dixidae

138. Dixidae (?) pupa--a single pupa of what appears to be a member of this family was collected in December at the Peace River, Hardee Co.

Collection: 102.

Density: .063/plant or 5/m^2.

Dolichopodidae Pupa

139. Dolichopodidae (?) pupa--a single pupa of this family was collected in November at a drainage ditch in Alachua Co.

Collection: 40.

Density: .03/plant.

Psychodidae Larva

140. Psychodidae larva--1 larva was collected in January at a drainage ditch in Alachua Co.

Collection: 51.

Density: .043/plant.

Stratiomyidae (Soldier Fly) Larvae

With 97 specimens, the stratiomyids comprised only 7.6% of the Diptera (1.8% of total) but still were my second most abundant dipteran family. This family was well-represented, with 3 genera being found in 34 of my 88 collections. Fifteen specimens of the genus *Myxosargus*, which comprised 81% of my stratiomyids, key out as *Euparyphus* in Pennak (1953) and Wirth and Stone (1968). McFadden (1967), whose key I used, has not yet confirmed my identifications. O'Hara (1961) found stratiomyid larvae occasionally abundant while Katz (1967) recorded 3 genera, *Odontomyia*, *Stratiomyia* and *Euparyphus*.

141. *Hedriodiscus* sp. larvae--11 specimens in 6 collections from 2 locations in Alachua Co.

Collections: 39, 40, 43, 51, 76, 88.

Maximum density: .125/plant at #88; 7.5/m^2 at #75.

142. Myxosargus sp. larvae and pupae--79 specimens in 27 collections from 6 locations in Alachua Co.

Collections: 2, 11, 13, 24, 31, 33, 34, 35, 39, 41, 49, 50, 51, 52, 53, 54, 55, 56, 69, 70, 72, 81, 84, 86, 89, 92, 95.

Maximum density: .32/plant at #34; 30/m^2 at #69.

Water quality preference: alkalinity, r=.872, p=.005, n=8; hardness, r=.892, p=.003, n=8; nitrates, r=-.872, p=.002, n=9.

Insect associations: Mesovelia sp. nymphs, r=-.746, p=.013, n=10; Desmopachria grana, r=.844, p=.034, n=6; Pachydrus obniger larvae, r=.889, p=.018, n=6.

These larvae, which will key to Euparyphus in most keys, were my third most abundant Diptera species and were represented in 30.7% of my collections. It was positively associated with Desmopachria grana beetles and with Pachydrus obniger larvae. Highly significant correlations indicate that this species prefers water high in hardness and low in nitrates. It was collected throughout the year.

143. Stratiomyid sp. C-- 5 specimens in 5 collections from 3 locations in Alachua Co.

Collections: 52, 53, 55, 83, 89.

Maximum density: .059/plant or 5/m^2 at #83.

These larvae differed from my other stratiomyid larvae in that they lacked the posterior plumose setae and the paired hooks on the next-to-last ventral segment. All my specimens were collected either in February or August.

Unidentified Stratiomidae larvae--2 specimens from 2 collections at Lake Alice, Alachua Co.

Collections: 32, 36.

Stratiomyid larvae which were too poorly preserved (after rearing attempts) to identify were placed in this group.

Syrphidae (Flower Flies) Larvae

144. *Eristalis* sp. larvae--9 specimens in 6 collections from 3 locations in Alachua Co.

Collections: 13, 33, 35, 36, 91, 94.

Maximum density: .10/plant at #36; 5/m^2 at #94.

Rat-tailed maggots, as the larvae of this genus are known, were collected only occasionally between July and October. Katz (1967) also reports this genus from one of her collections.

Tabanidae (Horse Flies) Larvae

Only 3 larvae belonging to 2 different genera were collected of this family.

145. *Chrysops* sp. larva--1 larva collected in June at a culvert in Charlotte Co.

Collection: 79.

Density: .010/plant or 5/m^2.

146. *Tabanus* sp. larvae--2 specimens from 2 locations in 2 counties.

Collections: 79, 83.

Maximum density: .059/plant or 5/m^2 at #83.

Tipulidae Larvae

147. Tipulidae larvae (unidentified)--6 larvae in 5 collections from 4 locations in 2 counties.

Collections: 34, 37, 42, 43, 44.

These larvae were never common and were collected only in October and December. Although several were reared to adult stage, none have yet been identified. Katz (1967) reports the genus *Helius* from 2 of her collections.

Diptera--Unidentified

Unidentified Diptera pupae--5 specimens in 4 collections from 3 locations in Alachua Co.

Collections: 49, 57, 72, 81.

These pupae, belonging to the suborder Cyclorrapha, could not be identified. Since I was not sure even if they represented aquatic species, as opposed to having been washed in from shore or overhanging vegetation, these forms were omitted from my analyses.

per plant and per square meter are also given. Similarities or discrepancies with the lists of aquatic insects presented by O'Hara (1961, 1968) and Katz (1967) are mentioned. Any apparent seasonal or locality preferences are also noted.

Due to the length of the list, I will include here some general observations on its content.

Mayfly nymphs and dobsonfly larvae were uncommon, while moth and caddisfly larvae were rare. Aquatic Hemiptera, comprising 9.2% of the total specimens, were frequently collected but usually were not particularly abundant at any site. Of the Diptera, which comprised 23.1% of all specimens, only the chironomid and stratiomyid larvae were frequently collected, with the former sometimes being extremely abundant. Several species of damselfly nymphs were frequent, with one species, Ischnura posita, being the most frequently collected aquatic insect species. Sixty-four species of beetles, comprising 45.5% of the specimens, were present, with the noterids and several species of dytiscids being abundant and frequent. Table 3 lists the 10 most abundant species (greatest number of specimens), while Table 4 presents the 10 most frequent species (present in the greatest number of different collections).

The species marked with asterisks obtain oxygen directly from the water. Since waterhyacinth mats frequently have been noted for the complete absence of dissolved oxygen (DO) beneath them (Lynch et al. 1947, Ultsch 1971, 1973), few such forms would be expected. Yet almost 33% of the specimens belonging to the 10 most abundant species utilize DO. This indicates

Table 3. Ten most abundant insects collected from waterhyacinth roots (from 88 collections, 1972-1974).

Rank	Species	N	Col.	% Total
1.	*_Chironomus attenuatus_ Walker (Diptera:Chironomidae)	760	25	13.9
2.	_Suphisellus insularis_ (Sharp) (Coleoptera:Noteridae)	549	33	10.0
3.	_Suphisellus gibbulus_ (Aube) (Coleoptera:Noteridae)	332	36	6.1
4.	*_Ischnura posita_ (Hagen) (Odonata:Coenagrionidae)	319	47	5.8
5.	_Hydrovatus compressus_ Sharp (Coleoptera:Dytiscidae)	276	36	5.0
6.	*_Telebasis byersi_ Westfall (Odonata:Coenagrionidae)	220	26	4.0
7.	_Colpius inflatus_ (LeConte) (Coleoptera:Noteridae)	177	23	3.2
8.	*_Polypedilum illinoense_ (Malloch) (Diptera:Chironom.)	156	13	2.8
9.	*_Enallagma signatum-pollutum_ complex (Odonata: Coenagrionidae)	119	22	2.2
10.	*_Miathyria marcella_ (Selys) (Odonata:Libellulidae)	116	30	2.1
				55.1

*Denotes dissolved oxygen-breathing form

Table 4. Ten most frequent insects collected from waterhyacinth roots (from 88 collections, 1972-1974).

Rank	Species	Col.	N
1.	*_Ischnura posita_ (Hagen) (Odonata:Coenagrionidae)	47	319
2.	_Suphisellus gibbulus_ (Aube) (Coleoptera:Noteridae)	36	332
2.	_Hydrovatus compressus_ Sharp (Coleoptera:Dytiscidae)	36	276
2.	_Hydrocanthus regius_ Young (Coleoptera:Noteridae)	36	104
5.	_Suphisellus insularis_ (Sharp) (Coleoptera:Noteridae)	33	549
6.	_Pelocoris balius_ La Rivers (Hemiptera:Naucoridae)	31	107
7.	*_Pachydiplax longipennis_ (Burmeister) (Odonata:Libellul.)	30	111
8.	_Pelocoris femoratus_ (Palisot-Beauvois) (Hemiptera: Naucoridae)	29	87
9.	_Myxosargus_ sp. larvae (Diptera:Stratiomyidae)	27	79
10.	_Hydrocanthus oblongus_ Sharp (Coleoptera:Noteridae)	26	60

*Denotes dissolved oxygen-breathing form that either the DO measurements are in error or that these insects locate oxygen in some manner, perhaps from gas bubbles on waterhyacinth roots.

Insect populations beneath waterhyacinths were generally high. Only 7 collections contained less than 10 specimens, whereas one beetle (Suphisellus insularis) was found at a density of $337/m^2$ of waterhyacinth mat and a chironomid (Chironomus attenuatus) was found at a density of $580/m^2$.

While certain species had significant correlations with water chemistry parameters, no general water quality preferences were noted for larger taxonomic groups. Congeneric species sometimes had completely different water quality preferences, perhaps indicating that these parameters act as isolating mechanisms for these species.

Usually the biological significance of correlations between pairs of species was ambiguous since direct observations of interaction between the species would be necessary to elucidate the reasons for the relationships.

Comparison of my species list with O'Hara's (1961) list, which usually identified aquatic insects only to family level, was noteworthy for O'Hara's omission of certain groups such as noterids, which I found to be extremely frequent and abundant. I believe that he misidentified Noteridae as Omophronidae.

Inspection of Katz's (1967) list, where most insects were identified to genera, revealed quite a few probable misidentifications, probably due to her reliance on a single set of identification keys (Pennak 1953) which omits many Florida genera.

Some species showed definite seasonality in their abundance. However, seasonal abundance seemed to vary with the species and generalizations about higher taxon levels such as families or orders do not appear to be valid. For instance, one beetle species, *Hydrovatus compressus*, reached peak densities during late winter while its congener, *H. peninsularis*, reached peak densities in late summer.

Physical and Chemical Variable Interrelationships

Correlation analyses were run on the physiometric plant measurements and the chemical water quality data. All the numeric data were "normalized" by taking the natural logarithms of the values, this log transformation being common in multivariate analyses of aquatic data (Green 1971, Stimac and Leong 1977).

The height of waterhyacinth plants was highly significantly correlated (the p level for significance of the r correlation statistic was .01 or less) with depth and water temperature; had highly significant negative correlations with chlorides, sulphate and sodium; and had significant (p level less than .05) negative correlations with hardness, iron and conductivity. Root length had a negative significant correlation with depth, which was positively correlated with height. Thus deeper waters were more likely to have taller waterhyacinths with shorter roots. This is directly opposite to Goin's (1943) statement that root length varies directly with water depth. The depth of the water had a highly significant correlation with the number of specimens and species, a significant correlation with magnesium, and significant negative correlations with iron and potassium.

As can be seen from Table 5, which presents the correlation matrix for the water quality data, almost all the water chemistry parameters are interrelated. This makes analyses of the relationships of these parameters very difficult, since most multivariate statistical procedures assume that the independent variables are linear (orthogonal) in respect to each other, *i.e.*, the independent variables are assumed to be uncorrelated.

Regression Analyses

Stepwise multiple regression analyses of the data for all collections did not reveal any variable or combination of variables which were significant in their effects on the numbers of species or specimens collected.

Comparison of Study Sites

Description

Three sites in Alachua County were sampled repetitively during the duration of the study. The most intensively studied area was Camps Canal, which drains a portion of Payne's Prairie into Orange Lake. Located northeast of Micanopy on State Road 234, about 10 meters wide, with steep sides quickly dropping to a depth of 2+ meters, this site had a jam of water-hyacinths at the SR 234 bridge. At the beginning of the

Table 5. Correlation matrix for water quality data.

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	PH	TEMP	ALK	CHLOR	HARD	IRON	NITRATE	PHOSPH	POTAS	SULF	CONDUC	MAGNES	SODIUM
PH	1.00000 0.0000 35	-0.08271 0.6697 29	0.71740 0.0001 33	0.13137 0.4590 34	0.75839 0.0001 32	0.06865 0.8005 16	0.28986 0.0912 35	-0.03534 0.8355 35	0.50225 0.0034 32	0.55968 0.0127 19	0.73198 0.0001 33	0.29729 0.0877 34	0.49703 0.0028 34
TEMP	-0.08271 0.6697 29	1.00000 0.0000 29	0.00418 0.9831 28	-0.53992 0.0030 28	-0.16692 0.4053 27	-0.64016 0.0102 15	-0.62572 0.0003 29	0.17193 0.3725 29	-0.33738 0.0852 27	-0.05124 0.8539 14	-0.03947 0.8420 28	0.74812 0.0001 29	-0.06435 0.7402 29
ALK	0.71740 0.0001 33	0.00418 0.9831 28	1.00000 0.0000 33	0.30092 0.0942 32	0.96047 0.0001 32	-0.00908 0.9734 16	-0.13637 0.4492 33	0.43166 0.0121 33	0.25601 0.1645 31	0.68945 0.0015 18	0.91322 0.0001 32	0.52633 0.0017 33	0.60330 0.0002 33
CHLOR	0.13137 0.4590 34	-0.53992 0.0030 28	0.30092 0.0942 32	1.00000 0.0000 34	0.40511 0.0234 31	0.35944 0.1715 16	0.11326 0.5236 34	0.29610 0.0891 34	0.30643 0.0936 31	0.52733 0.0245 18	0.41316 0.0188 32	-0.02219 0.9025 33	0.50654 0.0002 33
HARD	0.75839 0.0001 32	-0.16692 0.4053 27	0.96047 0.0001 32	0.40511 0.0234 31	1.00000 0.0000 32	0.10101 0.7202 15	-0.02495 0.8922 32	0.40550 0.0213 32	0.38375 0.0363 30	0.80717 0.0001 17	0.95834 0.0001 31	0.52220 0.0022 32	0.69355 0.0001 32
IRON	0.06865 0.8005 16	-0.64016 0.0102 15	-0.00908 0.9734 16	0.35944 0.1715 16	0.10101 0.7202 15	1.00000 0.0000 16	0.55800 0.0247 16	-0.22787 0.3960 16	0.27103 0.3099 16	0.80132 0.1987 4	-0.01193 0.9650 16	-0.62453 0.0097 16	0.21514 0.4235 16
NITRATE	0.28986 0.0912 35	-0.62572 0.0003 29	-0.13637 0.4492 33	0.11326 0.5236 34	-0.02495 0.8922 32	0.55800 0.0247 16	1.00000 0.0000 35	-0.34357 0.0433 35	0.22771 0.2101 32	-0.14960 0.5410 19	-0.07437 0.6808 33	-0.61936 0.0001 34	-0.08480 0.6335 34
PHOSPH	-0.03534 0.8355 35	0.17193 0.3725 29	0.43166 0.0121 33	0.29610 0.0891 34	0.40550 0.0213 32	-0.22787 0.3960 16	-0.34357 0.0433 35	1.00000 0.0000 35	-0.16792 0.3583 32	0.51088 0.0254 19	0.49904 0.0031 33	0.41124 0.0157 34	0.36786 0.0323 34
POTAS	0.50225 0.0034 32	-0.33738 0.0852 27	0.25601 0.1645 31	0.30643 0.0936 31	0.38375 0.0363 30	0.27103 0.3099 16	0.22771 0.2101 32	-0.16792 0.3583 32	1.00000 0.0000 32	0.43615 0.0912 16	0.40243 0.0248 31	0.03498 0.8493 32	0.53497 0.0016 32
SULF	0.55968 0.0127 19	-0.05124 0.8539 14	0.68945 0.0015 18	0.52733 0.0245 18	0.80717 0.0001 17	0.80132 0.1987 4	-0.14960 0.5410 19	0.51088 0.0254 19	0.43615 0.0912 16	1.00000 0.0000 19	0.81442 0.0001 17	0.61057 0.0071 18	0.69379 0.0014 18
CONDUC	0.73198 0.0001 33	-0.03947 0.8420 28	0.91322 0.0001 32	0.41316 0.0188 32	0.95834 0.0001 31	-0.01193 0.9650 16	-0.07437 0.6808 33	0.49904 0.0031 33	0.40243 0.0248 31	0.81442 0.0001 17	1.00000 0.0000 33	0.52939 0.0015 33	0.72787 0.0001 33
MAGNES	0.29729 0.0877 34	0.74812 0.0001 29	0.52633 0.0017 33	-0.02219 0.9025 33	0.52220 0.0022 32	-0.62453 0.0097 16	-0.61936 0.0001 34	0.41124 0.0157 34	0.03498 0.8493 32	0.61057 0.0071 18	0.52939 0.0015 33	1.00000 0.0000 34	0.44146 0.0090 34
SODIUM	0.49703 0.0028 34	-0.06435 0.7402 29	0.60330 0.0002 33	0.50654 0.0002 33	0.69355 0.0001 32	0.21514 0.4235 16	-0.08480 0.6335 34	0.36786 0.0323 34	0.53497 0.0016 32	0.69379 0.0014 18	0.72787 0.0001 33	0.44146 0.0090 34	1.00000 0.0000 34

Note: p-level less than .05 is significant; p-level less than .01 is highly significant.

growing season this jam consisted of a few patches of plants in front of the bridge, but by early fall the jam stretched over 100 meters upstream. A preliminary collection of aquatic insects was made in August of 1972, with intensive sampling begun in June of 1973. With the exception of late winter and early spring when the waterhyacinths had almost disappeared, another 28 collections were made at 2- to 3-week intervals until the end of 1974.

Lake Alice, a shallow lake of about 33 hectares on the University of Florida campus, was the second most intensively sampled site, with 12 collections. A preliminary collection was made in August of 1972, with the others made at odd intervals throughout the latter part of 1973 and until August of 1974. Almost all my collections were made from the boardwalk at the east end of the lake where depth was usually about 1-1½ meters. Suitability for sampling varied with the season and, more importantly, with the extent of the mechanical and chemical waterhyacinth control measures being used at the time.

My third study site was a drainage ditch on the east side of Interstate 75, 3.0 miles north of the Micanopy interchange. Consisting essentially of a small pond less than 10 meters wide surrounding a 2½ meter deep hole, this site was sampled 9 times beginning in July of 1973 when I first discovered it. Unfortunately, the encroachment by the water-penny, <u>Hydrocotyle</u> sp., was very rapid and by February 1974 there were few waterhyacinths left. When my last sample was taken in August of 1974, there was only a tiny stand of pure waterhyacinths remaining. Today the site is terrestrial grasses and shrubs with a few cattails in the deep hole.

Species List Comparisons

Camps Canal was my most intensively studied site and produced 2100 specimens of aquatic insects belonging to 96 species. Table 6 shows the 10 most abundant species and Table 7 shows the 11 most frequently collected species. Diptera larvae, especially chironomids, were exceptionally abundant. Both species of naucorids were frequently collected here. Ischnura posita was the most common damselfly here, as it was at many collecting sites, but members of the Enallagma signatum-pollutum complex were also common. By common I mean both abundant and frequent. The noterid Colpius inflatus was the most abundant beetle, and 3 other members of this family were frequently collected here. This was the only site where hydrophilid beetles were frequent. Caddisfly larvae as well as Megaloptera were collected almost exclusively at Camps Canal.

Lake Alice (see Tables 8 and 9), with 1283 specimens and 55 species, had the greatest percentage of DO-breathing insects of the 3 study sites. It was the only study site at which mayfly nymphs made up more than 1% of the insects found there. Odonata nymphs were abundant and among the damselfly species, I. posita nymphs were common, although not as common as those of Telebasis byersi, which was uncommon elsewhere. Beetles were the most common group, with Suphisellus

Table 6. Ten most abundant insects collected from waterhyacinth roots, Camps Canal (from 29 collections, 1972-1974).

Rank	Species	N	Col.	% Total
1.	*_Chironomus attenuatus_ Walker (Diptera:Chironomidae)	346	11	16.5
2.	*_Ischnura posita_ (Hagen) (Odonota:Coenagrionidae)	209	16	9.9
3.	*_Polypedilum illinoense_ (Malloch) (Diptera:Chironom.)	138	6	6.6
4.	_Colpius inflatus_ (LeConte) (Coleoptera:Noteridae)	105	16	5.0
5.	_Pelocoris balius_ La Rivers (Hemiptera:Naucoridae)	84	17	4.0
6.	_Suphisellus gibbulus_ (Aube) (Coleoptera:Noteridae)	73	11	3.5
7.	_Pelocoris femoratus_ (Palisot-Beauvois) (Hemiptera: Naucoridae)	71	19	3.4
8.	*_Enallagma signatum-pollutum_ complex (Odonata: Coenagrionidae)	68	12	3.2
9.	*_Parachironomus_ sp. (Diptera:Chironomidae)	67	3	3.2
10.	_Hydrovatus peninsularis_ Young (Coleoptera:Dytiscidae)	57	8	2.7
				58.0

*Denotes dissolved oxygen breathing form

Table 7. Ten most frequent insects collected from waterhyacinth roots, Camps Canal (from 29 collections, 1972-1974).

Rank	Species	Col.	N
1.	_Hydrocanthus regius_ Young (Coleoptera:Noteridae)	21	73
2.	_Pelocoris femoratus_ (Palisot-Beauvois) (Hemiptera: Naucoridae)	19	71
3.	_Pelocoris balius_ La Rivers (Hemiptera:Naucoridae)	17	84
4.	*_Ischnura posita_ (Hagen) (Odonata:Coenagrionidae)	16	209
4.	_Colpius inflatus_ (LeConte) (Coleoptera:Noteridae)	16	105
6.	_Myxosargus_ sp. (Diptera:Stratiomyidae)	14	46
7.	*_Enallagma signatum-pollutum_ complex (Odonata: Coenagrionidae)	12	68
7.	_Hydrocanthus oblongus_ Sharp (Coleoptera:Noteridae)	12	23
9.	*_Chironomus attenuatus_ Walker (Diptera:Chironomidae)	11	346
9.	_Suphisellus gibbulus_ (Aube) (Coleoptera:Noteridae)	11	52
9.	_Phaenotum exstriatus_ Say (Coleoptera:Hydrophilidae)	11	20

*Denotes dissolved oxygen breathing form

Table 8. Ten most abundant insects collected from waterhyacinth roots, Lake Alice (from 12 collections, 1972-1974).

Rank	Species	N	Col.	% Total
1.	*Suphisellus insularis* (Sharp) (Coleoptera:Noteridae)	420	12	32.7
2.	*Hydrovatus compressus* Sharp (Coleoptera:Dytiscidae)	175	11	13.6
3.	**Telebasis byersi* Westfall (Odonata:Coenagrionidae)	169	3	13.2
4.	**Chironomus attenuatus* Walker (Diptera:Chironomidae)	111	9	8.6
5.	*Mesonoterus addendus* (Blatchley) (Coleoptera: Noteridae)	62	10	4.8
6.	**Ischnura posita* (Hagen) (Odonata:Coenagrionidae)	39	9	3.0
7.	**Pachydiplax longipennis* (Burmeister) (Odonata: Libellulidae)	25	4	1.9
8.	*Suphisellus* sp. larvae (Coleoptera:Noteridae)	23	4	1.8
9.	**Callibaetis floridanus* Banks (Ephemeroptera:Baetidae)	18	3	1.4
10.	*Myxosargus* sp. larvae (Diptera:Stratiomyidae)	15	7	1.2
				82.2

*Denotes dissolved oxygen breathing form

Table 9. Ten most frequent insects collected from waterhyacinth roots, Lake Alice (from 12 collections, 1972-1974).

Rank	Species	Col.	N
1.	*Suphisellus insularis* (Sharp) (Coleoptera:Noteridae)	12	420
1.	**Telebasis byersi* Westfall (Odonata:Coenagrionidae)	12	169
3.	*Hydrovatus compressus* Sharp (Coleoptera:Dytiscidae)	11	175
4.	*Mesonoterus addendus* (Blatchley) (Coleoptera:Noteridae)	10	62
5.	**Ischnura posita* (Hagen) (Odonata:Coenagrionidae)	9	39
5.	*Hydrocanthus regius* Young (Coleoptera:Noteridae)	9	14
7.	*Myxosargus* sp. (Diptera:Stratiomyidae)	7	15
7.	*Pelocoris balius* La Rivers (Hemiptera:Naucoridae)	7	9
9.	**Chironomus attenuatus* Walker (Diptera:Chironomidae)	6	111
10.	*Celina* sp. larvae (Coleoptera:Dytiscidae)	5	10

*Denotes dissolved oxygen breathing form

insularis the most common insect at this site. Almost 90% of all the specimens of another noterid, *Mesonoterus addendus*, were collected here.

A total of 661 specimens belonging to 46 species was collected at the I-75 drainage ditch site. Table 10 presents the 10 most abundant species and Table 11 shows the 10 most frequently collected species at this site. Probably the most noteworthy point is the frequency and abundance of the Helodidae beetle larvae belonging to the genus *Ora*. This genus was not found at any other site. The larvae of *Scirtes*, another helodid, were also common here but uncommon everywhere else. The relatively high abundance of *Culex territans*, a genus of mosquito which was not collected elsewhere, is probably due to the hatching of a single egg raft. The noterid beetle, *Suphisellus puncticollis*, was also relatively abundant here, with almost half of the 44 specimens of this species being collected at this site. This site had relatively fewer DO-breathing forms (noted with an asterisk), perhaps indicating a greater tendency towards anaerobic conditions.

The use of discriminant analysis demonstrated that the different abundances of these various species of insects were not due to chance. By performing a Hotelling T^2 test on the generalized squared distance to the group, an F-value for testing the significance of difference between any 2 groups could be evaluated (Morrison 1967). In this manner it was found that the abundances of the insect species at Camps Canal were highly significantly different from those at both Lake Alice and the drainage ditch. Lake Alice was significantly

Table 10. Ten most abundant insects collected from waterhyacinth roots, I-75 drainage ditch (from 9 collections, 1972-1974).

Rank	Species	N	Col.	% Total
1.	*Suphisellus gibbulus* (Aube) (Coleoptera:Noteridae)	233	7	35.2
2.	*Ora* spp. larvae (Coleoptera:Helodidae)	92	8	13.9
3.	**Ischnura posita* (Hagen) (Odonata:Coenagrionidae)	39	6	5.9
4.	*Belostoma* sp. nymphs (Hemiptera:Belostomatidae)	34	4	5.1
5.	*Scirtes* sp. larvae (Coleoptera:Helodidae)	25	5	3.8
6.	*Culex territans* Walker (Diptera:Culicidae)	24	1	3.6
7.	*Suphisellus puncticollis* Crotch (Coleoptera:Noteridae)	21	5	3.2
8.	*Colpius inflatus* (LeConte)(Coleoptera:Noteridae)	20	3	3.0
9.	*Hydrovatus peninsularis* Young (Coleoptera:Dytiscidae)	16	5	2.4
10.	*Belostoma testaceum* (Leidy)(Hemiptera:Belostomatidae)	15	6	2.3

*Denotes dissolved oxygen breathing form

Table 11. Ten most frequent insects collected from waterhyacinth roots, I-75 drainage ditch (from 9 collections, 1972-1974).

Rank	Species	Col.	N
1.	*Ora* spp. larvae (Coleoptera:Helodidae)	8	92
2.	*Suphisellus gibbulus* (Aube) (Coleoptera:Noteridae)	7	233
3.	**Ischnura posita* (Hagen) (Odonata:Coenagrionidae)	6	39
3.	**Telebasis byersi* Westfall (Odonata:Coenagrionidae)	6	13
3.	*Belostoma testaceum* (Leidy) (Hemiptera:Belostomatidae)	6	11
6.	*Scirtes* sp. larvae (Coleoptera:Helodidae)	5	25
6.	*Suphisellus puncticollis* Crotch (Coleoptera:Noteridae)	5	21
6.	*Hydrovatus peninsularis* Young (Coleoptera:Dytiscidae)	5	16
9.	*Belostoma* sp. nymphs (Hemiptera:Belostomatidae)	4	34
10.	**Polypedilum illinoense* (Malloch)(Diptera:Chironomidae)	4	4

*Denotes dissolved oxygen breathing form

different (and just shy of being highly significantly different) from the drainage ditch. These comparisons were based on the abundances of only the 10 most frequent species overall (see Table 3). As the last part of the discriminant analysis, the SAS program classifies each collection as to which site it should have come from based on the abundances of these 10 species. Only 3 collections (2 from the drainage ditch, 1 from Lake Alice) out of the 50 were classified incorrectly. This technique with its ability to discriminate between 3 similar, eutrophic, waterhyacinth-filled, aquatic sites, based just on the abundances of 10 species of insects, could have a very real practical value for those engaged in monitoring and classifying aquatic ecosystems. Only a relatively few frequently-encountered species would have to be identified in order to compare an aquatic ecosystem with others or with previous collections from the same site. The need for locating certain bioindicators of water quality or the measurement of dynamic, rapidly fluctuating water chemistries would be eliminated.

Estimation of Total Number of Species

Plots of the cumulative number of species versus the cumulative number of specimens were made for each of the study sites. After obtaining estimates of b and of S^*, the estimated number of species in the study area, through the procedure discussed in the methods section, an exponential curve was fitted to the data using SAS PROC NLIN. The Marquardt method, a least-squares approach, was used for the fitting of the curve, although the other optional methods gave virtually identical curves. The F-value for the goodness of fit was over 150, extremely significant, for all 3 curves fitted in this manner.

As can be seen from Fig. 3, the species accumulation curve for Camps Canal becomes asymptotic at a value of 90.2 species. The standard error for the estimated asymptote is 1.78, with the 95% confidence interval being S* ± 2 standard error. Since 96 species were actually found at Camps Canal, this gives a sampling efficiency of 106.5%. Several factors help explain why the predicted number of species is lower than the actual number of species found. The least squares approach and most other statistical methods of curve fitting will usually, if the variation in the data is similar, result in a line where approximately an equal number of points are above and below the curve. In this case some of the points above the curve are near the end where the curve becomes asymptotic. This statistical approach to fitting a curve makes no assumptions as to the distribution of specimens among species or minimum level for the asymptote.

Another factor leading to a low estimate of total species is the abrupt addition of seasonal and possibly even successional forms. As can be seen from Fig. 3, the number of species begins to increase in the beginning of May (point A), starts to level off by late June (point B), and stays at a steady level of species until the end of August (point C). The new species,

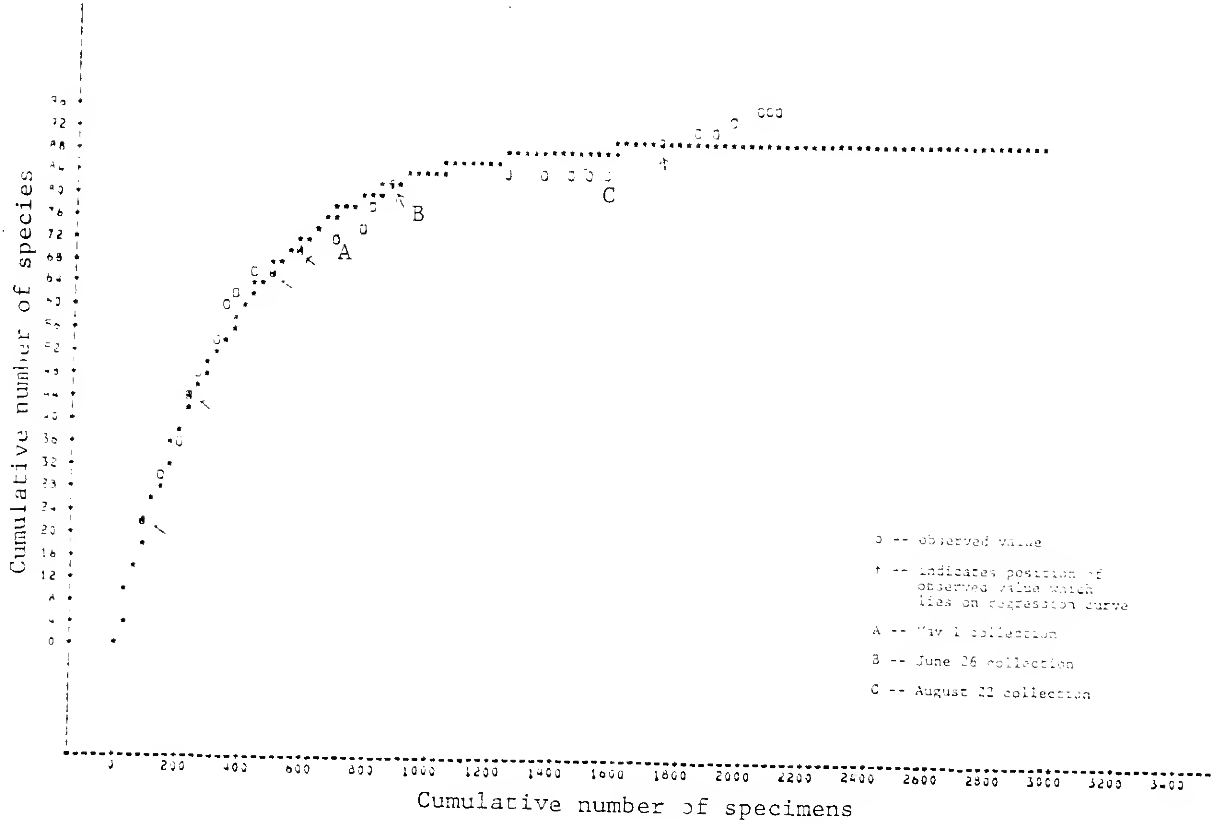

Figure 3. Species accumulation curve for Camps Canal.

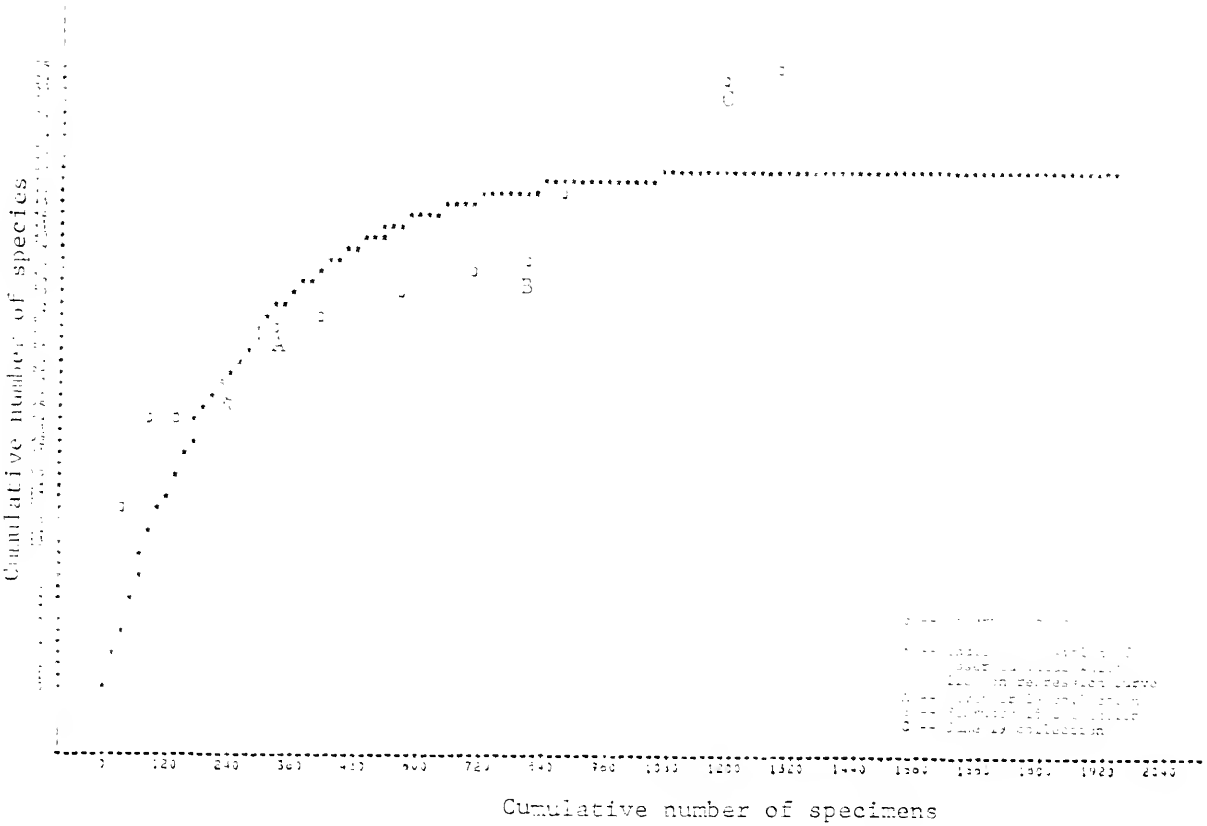

Figure 4. Species accumulation curve for Lake Alice.

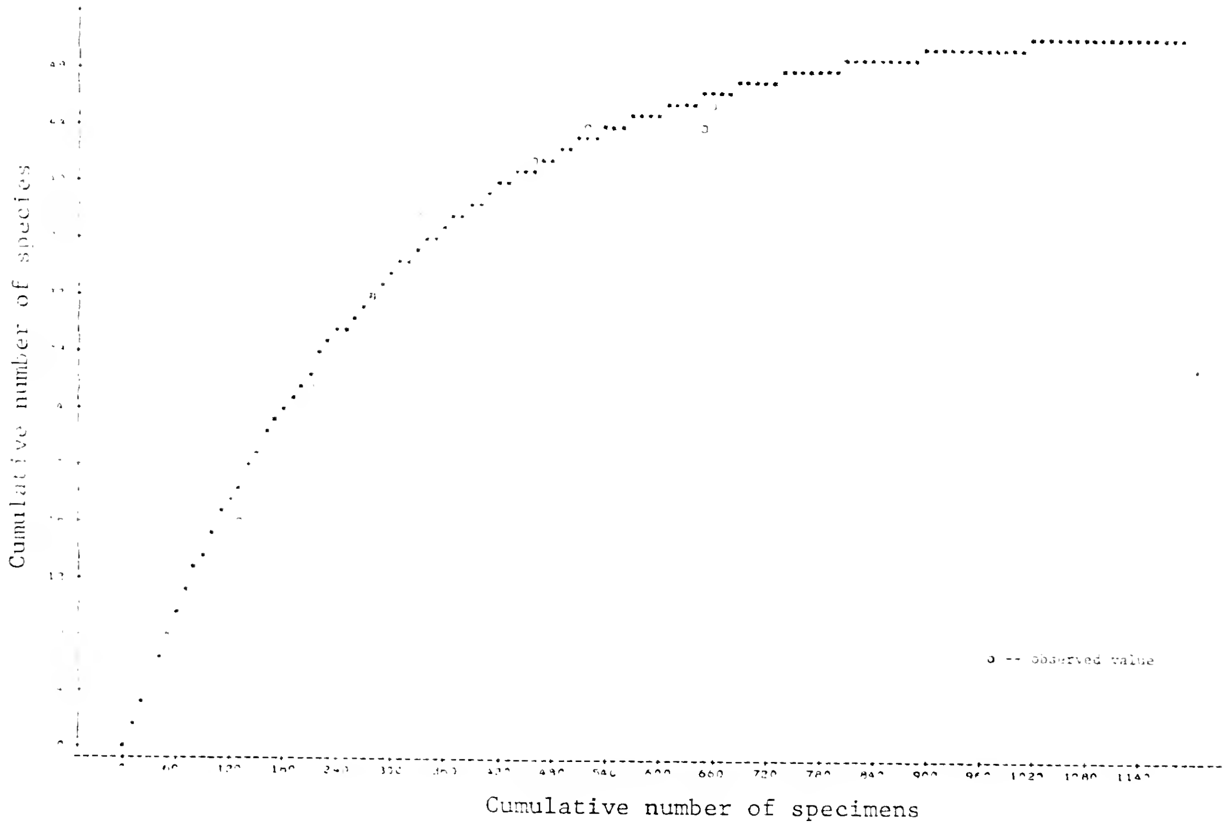

Figure 5. Species accumulation curve for I-75 drainage ditch.

mostly Hemiptera, appearing in May are not necessarily increasing the number of species actually present since some probably replace species, such as emerging damselflies, no longer present at the sampling site. If many collections (say 25) were made per season, the resultant species accumulation curve would probably show a series of steps of decreasing size, marking seasonal turnover of species for the first few years. For a relatively short term of study like this (essentially 1½ years), the asymptote predicted is heavily influenced by last series of collections which show no new species, i.e. the last seasonal asymptote reached. Thus, since my study ended shortly after the winter level of species was reached, the predicted asymptote was therefore influenced by the lower value reached during the preceding summer.

This seasonal factor is also present in the estimation for the total number of specimens at Lake Alice. As can be seen from Fig. 4, the predicted number of total species is 46.2, while 55 species, 119% of the predicted value, were actually collected. Again, it appears that the period from Nov. 19 (point A) through Feb. 9 (point B), with its slow rate of acquisition of new species, influenced the predicted curve downward. There were not enough collections after June (point C) to establish the existence of a new asymptote (probably close to a value of 55) and to increase the predicted value of S*. It should also be noted the actual value of 55 species lies on the upper boundary of the 95% confidence interval limit for the mean (standard error = 3.91). Thus the underestimation may be due in part to the variation in the data.

There is too little data for the drainage ditch site to demonstrate seasonal changes in the number of species (see Fig. 5). For this study site the predicted total number of species, S*, is 51.5 (standard error = 2.53) and 46 species were actually collected, giving a sampling efficiency of 89.3%.

The species accumulation curve method appears to be a potentially useful tool in community ecology. A fairly good estimate of the total number of species in a sample site could be obtained if several years' worth of collections were used in order to minimize seasonal influences. A good estimate of the seasonal level of species could be obtained by intense sampling confined primarily to a single season. The plotting of a species accumulation curve is also a good method for demonstrating the size and timing of seasonal turnover of species.

Another way of estimating S* is to assume (or demonstrate) that the species are distributed in some set manner. In 1948 Preston proposed the lognormal distribution of species. The lognormal distribution pattern assumes that the specimens per species are distributed in a geometric or logarithmic series while the abundance of species has a normal distribution. Preston (1948, 1958, 1962) found that this lognormal distribution is very satisfactory in explaining the distribution of species abundances of a large variety of organisms, especially of insects. May, in his elegant review (1975) of distribution patterns and their effects on diversity, states that "For large or heterogeneous assemblies of species, a lognormal pattern of relative abundance may be expected" (p. 106). Thus, the assumption that my abundances of aquatic insect species are lognormally distributed seems to be well-founded. Actual, conclusive demonstration that this distribution pattern is the correct one is difficult since, as Price (1975) points out, ". . . a line can be fitted to any distribution data, and it does not mean that it is a good model, nor that the explanation for the fit is necessarily the only explanation" (p. 365). The lognormal distribution has intuitive appeal, its applicability to insects has been demonstrated, and this pattern allows the computation of S*, the total number of species.

Its main drawback, as mentioned in the methods section, is fitting a truncated normal curve to the data. Since I did not, at this time, have the necessary resources to do so statistically, I therefore fitted a curve to my data points visually. Fig. 6 shows a species abundance curve for the Camps Canal study site. By visual inspection, s_o, the number of species in the modal octave R_o, is approximately 16. Assuming a=0.2 (as shown by Preston 1948) and solving $S^*=s_o\sqrt{\pi}/a$, S*=141.8 species. This is quite a bit higher than the 90.2 species estimated by the species accumulation method or the actual 96 species collected. Sampling efficiency would be 67.7%.

The species abundance curve for Lake Alice is shown in Fig. 7. The number of species in the modal octave is approxi-

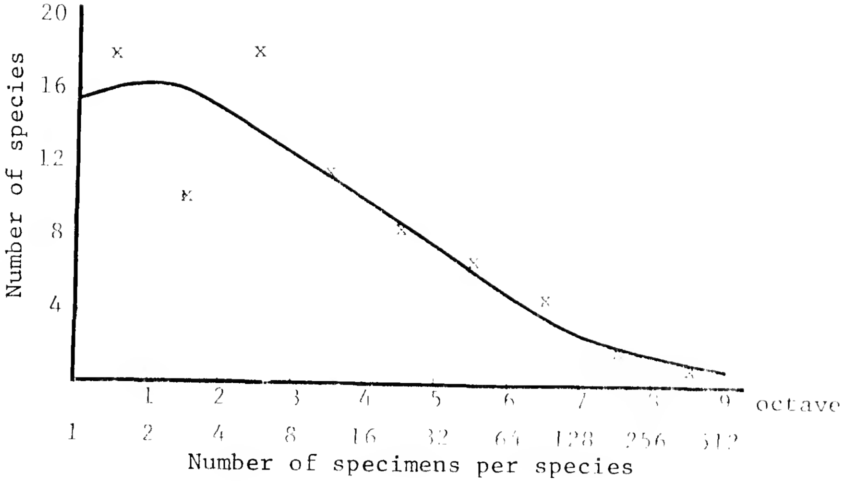

Figure 6. Species abundance curve for Camps Canal, visually fitted.

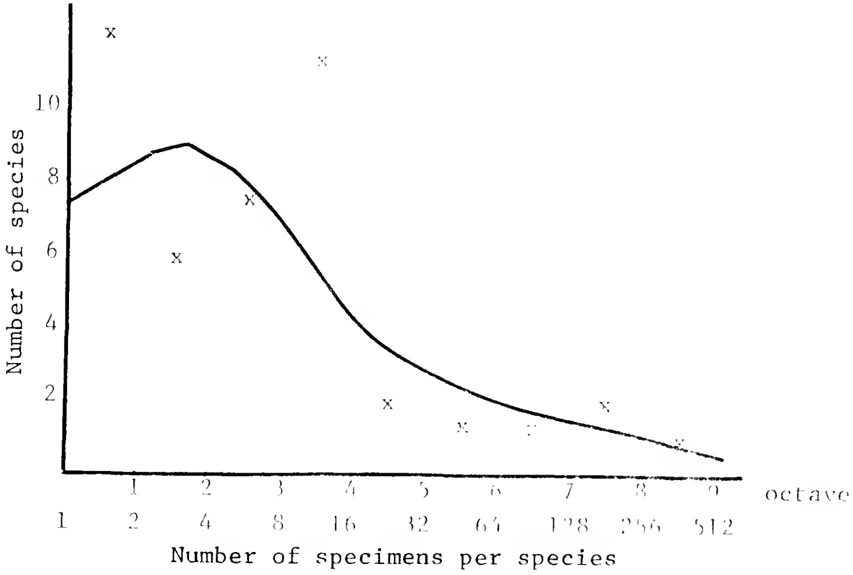

Figure 7. Species abundance curve for Lake Alice, visually fitted.

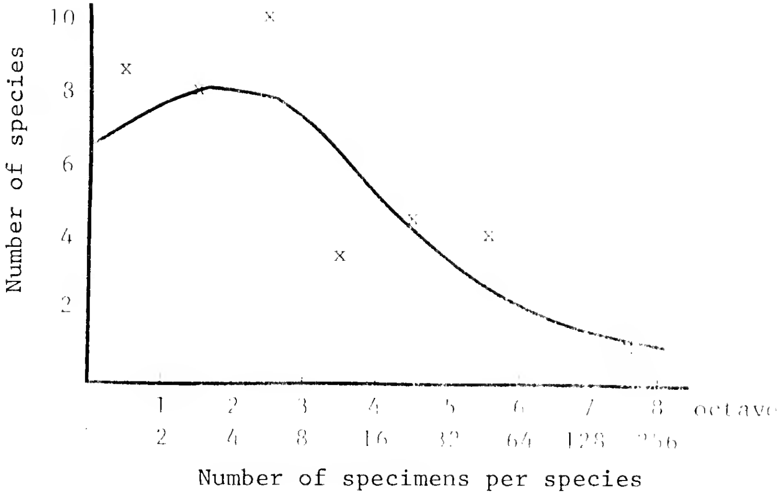

Figure 8. Species abundance curve for I-75 drainage ditch, visually fitted.

mately 9, resulting in a value of 79.8 species for the estimate of S*. This also is much higher than the 52 species estimated by the previous method or the 55 species actually collected. The calculated sampling efficiency now drops to 68.9%.

The species abundance for the I-75 drainage ditch is shown in Fig. 8. The number of species in the modal octave is approximately 8, which results in an estimated 70.9 species. This again is much more than the previously estimated S* of 51.5 species or the 46 species actually collected. Sampling efficiency for this site then becomes 64.9%.

While previously the estimated sampling efficiency was nearly 100% for all 3 sites, this figure drops down to under 70% using this crude approximation of Preston's lognormal curve method. If the actual value of a had been 0.227 (a value observed by Preston, 1948), then sampling efficiency would have increased to around 75%. Thus the high estimation of total species present at the sites may be partly due to assuming a low value of a. Another reason why species abundance method yields such high estimates of S* may be because a static relation between abundances of the various species is implicitly assumed. Thus, in estimates based on short-term collecting, seasonal and other variations affecting the relative proportions of species are magnified, resulting in a higher S*. Also, no doubt, there are probably some extra species in the collections which could not be determined because they were larval forms or pupae. However, these few species would have a minimal effect. A long-term study of many years, like most of the data analyzed by Preston, would smooth out seasonal variations and add new species and help confirm or refute the validity of this method.

Both the species abundance curve method and especially the species accumulation curve method could be employed to answer some interesting general ecological questions concerning species-area relationships as well as problems about the aquatic insect community of waterhyacinths. By collecting aquatic insects fairly intensively at 10 or more waterhyacinth communities in Florida whose area of infestation is known, an estimate of the number of species at each site could be made. Plotting the number of species versus the log of the area would allow comparison with MacArthur and Wilson's (1967) predicted relationship between the number of species and the size of islands.

If this procedure were then repeated in Argentina, the probable point of origin for waterhyacinths, and the slopes of the lines compared, evidence would be provided of whether the aquatic entomofauna of waterhyacinths has reached species saturation, since the introduction of waterhyacinth approximately 90 years ago. Saturation would be indicated if the number of species of aquatic insects in waterhyacinth communities in Florida was approximately the same as the number of species in Argentinian waterhyacinth communities of the same size. Strong (1974a) has indicated that tree insects in Britain reach saturation levels of species on trees within

300 years of their introduction of a new tree species. He (1974b) also has shown that the insect pests of cacao probably saturate within 72 years of the introduction of this plant to a new geographical area. Thus saturation of the number of aquatic insect species beneath waterhyacinths could have occurred in less than 100 years.

Factors Affecting the Number of Species and Genera

While stepwise multiple regression analyses of the data from all 88 collections revealed no significant variable or combination of variables which affected the number of species or specimens found, when the sites were considered separately this was no longer the case. Stepwise multiple regression analysis differs from simple multiple regression analysis in that each variable being considered is entered one at a time and its contribution to explaining the variation is then tested. Simple multiple regression forms a model consisting of all the variables being considered and then tests for significance. Since many variables do not have a significant effect, their addition to the model just adds "noise" and reduces the amount and significance of the variation explained. The maximum R^2 improvement method of stepwise regression, the method I used, calculates the amount of variation explained, R^2, for all possible models having that many variables before adding another variable to the model (see Barr *et al*. 1976).

Using this method, a highly significant model for the number of species found at Camps Canal was:

$$\text{species} = 14.229 + 16.448(\text{iron}) - .323(\text{root length}).$$

This model of the dependence of the number of species on the level of iron in the water and shorter root length explained 58.2% of the variation and was significant at p=.0083 level. The number of genera present at Camps Canal was significantly dependent only on the level of iron:

$$\text{genera} = 12.307 + 13.538(\text{iron}).$$

At Lake Alice the number of species present was dependent at a highly significant level (p=.0016) on the height and root length of the waterhyacinths:

$$\text{species} = 15.873 - .133(\text{height}) + .216(\text{root length}).$$

The number of genera at Lake Alice was similarly explained:

$$\text{genera} = 17.083 - .136(\text{height}) + .158(\text{root length}).$$

No significant combination of variables was found to explain the number of species and genera at the drainage ditch site.

Diversity Studies

General

If one assumes that the distribution of individuals among species, *i.e.*, the relative abundances of species, is significant, it would be of interest to determine what factors influence it. As I have demonstrated in the previous section that the differences in the numbers of individuals among different species at different sites were highly significant, a single statistic which expresses that relationship between number of individuals and number of species would be of great value in determining what factors influence this difference between distributions. An obvious choice is the use of a species diversity index, especially one that includes components for both richness and equitablility. Such indices are commonly used to determine the effects of various factors on the species composition of a community. Wilhm and Dorris (1968, Wilhm 1972) have demonstrated the use of Shannon's diversity index for stream insects in determining stream pollution, while Allan (1975) has used diversity of aquatic insects as a means of detecting the effects of altitude and substrate size.

Because the controversy about the choice and applicability of the various diversity indices made an a priori selection of a single index difficult, I used Shannon-Weaver's H', Simpson's D, and the rarefaction index $E(S_n)$. The rarefaction index was calculated at two levels, n=10 and n=25. As a check and for comparison purposes, the number of specimens per species, SPCMN/SPP, was also used. Table 12 presents the average values for these diversity indices at my 3 study sites and for all 88 collections. Duncan's multiple range test revealed no significant differences between the means of any single index at the 3 study sites.

Dependence on Sample Size

In order to facilitate comparison between different collections, a diversity index should be independent of the

Table 12. Means values ($\pm$ standard deviation) for various diversity indices at different collecting sites.

	Shannon's Index H'	Simpson's Index D	Rarefaction Index $E(S_{10})$	Rarefaction Index $E(S_{25})$	Specimens per species
Camps Canal (29 cllec)	2.055 ± 0.652 n = 29	0.805 ± 0.073 n = 29	5.952 ± 1.662 n = 28	10.535 ± 3.553 n = 27	4.914 ± 4.940 n = 29
Lake Alice (12 cllec)	1.933 ± 0.288 n = 12	0.783 ± 0.066 n = 12	5.217 ± 0.803 n = 12	8.463 ± 2.298 n = 12	6.959 ± 3.104 n = 12
I-75 Ditch (9 cllec)	1.907 ± 9.494 n = 9	0.758 ± 0.168 n = 9	5.414 ± 1.237 n = 9	8.980 ± 2.253 n = 8	5.403 ± 3.054 n = 9
Complete (88 cllec)	1.914 ± 0.595 n = 88	0.786 ± 0.184 n = 88	5.734 ± 1.447 n = 81	9.678 ± 3.215 n = 68	5.129 ± 6.805 n = 88

number of specimens. However, inspection of the correlations between the indices I used and the number of specimens revealed that this was not always the case. Shannon's index had a significant correlation and specimens per species were highly significantly correlated with the log-transformed values of the number of specimens, while the 2 rarefaction indices both had high negative correlations. When the untransformed values for the number of specimens was used, the significances of the correlations were the same except for Shannon's index, which no longer showed a significant relation to the number of specimens. Only Simpson's index consistently showed no correlation to sample size.

Relations to Plant Part Size, Depth, and Time of Year

Stepwise multiple regression of the waterhyacinth morphometric measurements (root length, height, root-shoot ratio), time of year and depth,on the various diversity indices revealed no significant relationships when the data from all 88 collections were used. However, when the data for each study site were considered separately, several significant and highly significant relations were discovered. This would indicate that the effects of any variable upon a diversity index are not constant but vary from location to location. Thus the length of waterhyacinth roots had a significant negative effect on Shannon's index at Camps Canal but a highly significant positive effect on this same index at Lake Alice. No significant relation to Shannon's index with any combination of the 5 variables being tested was found for the I-75 ditch study site. However, at this site, depth had a significant effect on Simpson's index, which showed no significant relationships to any of these variables at the other 2 sites. The rarefaction indices were found to be negatively related at a highly significant level with depth of water at Camps Canal, positively related at a highly significant level with root length at Lake Alice, while no significant relationships were revealed at the I-75 ditch study site. The number of specimens per species was not significantly related to any combination of the 5 variables at Lake Alice. At Camps Canal a 2-variable model, positive root length and depth, showed a highly significant effect in explaining the variation in specimens per species, while at the I-75 ditch this variation was explained at a highly significant level by a model influenced positively by root length and negatively by height.

It should be noted that even highly correlated variables such as depth and root length were used in these analyses. Stepwise regression analysis, in effect, compensates for correlated variables. If a variable is entered into the model, the variation explained by that variable is similar to that explained by the variables correlated with it. Thus a correlated variable would explain little additional variation and is usually not entered into the model until much later steps. For this reason, the statisticians at the University of Florida advise me that the use of all variables, including correlated ones, is justified in stepwise regression analysis (Dr. Ramon Littell, Mr. Walter Offen, personal communications.)

Relationships to Water Quality Parameters

Stepwise multiple regression analysis was also used to ascertain possible relations of water quality parameters to the various diversity indices. All 13 water quality parameters were included in the analyses. The 5 plant and site variables previously analyzed and the number of petioles per plant and the number of plants per meter were also included in the analyses. In this manner not only would the indirect effect of plant-water quality interactions be taken into account, but the relative importance of any variable could be judged by when it appeared in the model.

As in the previous stepwise regression analyses, a model was considered significant if the amount of variation explained was significant, i.e. the p-level for r^2 was less than .05, and if the coefficients for all the parameters included in the model were also significant. The model chosen as the "best" model was one which had the lowest p-level for r^2 and still had significant coefficients for all the parameters included in the model.

Water quality data were available only for 34 of my collections. Camps Canal had 12 collections with these data, while Lake Alice and the I-75 ditch did not have enough to be analyzed separately.

When all 34 collections having water quality data were analyzed, the results were not particularly enlightening. Either no significant model was found or a great number of parameters were included in the "best" model, making interpretation difficult. As noted in the previous analysis, a variable does not necessarily have the same effect on diversity at different locations. When Camps Canal was considered separately, fewer variables were required to provide the "best" model. Table 13 lists the 4 most important parameters affecting diversity at Camps Canal and overall. Inspection of the list provides some interesting generalizations. Most noteworthy was the importance of alkalinity (or one of the variables, such as pH or hardness, highly correlated with alkalinity) in its effects on diversity indices. Higher diversity was associated with low levels of alkalinity or one of its correlated parameters. Higher diversity was associated with high levels of iron, at least at Camps Canal. Root length and plant height were less important than water quality parameters, not appearing anywhere on the list.

Conclusions--Choice of Indices

All of the diversity indices showed extremely high correlations (p=.0001 or less) with one another, yet they did not respond the same way. The rarefaction diversity indices were most sensitive to environmental parameters but, unfortunately, also to sample size.

None of the indices was adequate in distinguishing between the three study sites. Since discriminant analysis could distinguish these sites on the basis of just the abundance of 10 species, this would indicate that the information lost by combining the species distributions into one statistic negates its usefulness as an analytical tool.

Table 13. List of collection site variables in order of entry into models of diversity indices.

Step entered	Camps Canal (n=12)			Complete (n=34)		
	Shannon's Index H'	Simpson's Index D	Rarefaction Index $E(S_n)$	Shannon's Index H'	Simpson's Index D	Rarefaction Index $E(S_n)$
1st variable	-hardness	-depth	-hardness	-alkalinity	-alkalinity	-potassium
2nd variable	-alkalinity	+iron	-alkalinity	+hardness	+phosphates	+nitrates
3rd variable	+iron	-potassium	+iron	-potassium	+nitrates	-alkalinity
4th variable	+sodium	+pH		+depth	+iron	-hardness
number of variables in "best" model	8 $r^2=.991$ $p=.0007$	4 $r^2=.887$ $p=.0007$	3 $r^2=.892$ $p=.0001$	no significant model	14 $r^2=.962$ $p=.0001$	8 $r^2=.871$ $p=.0001$

Van Emden and Williams (1974), Pielou (1969) and others have questioned the wisdom of combining species richness and species equitability into one statistic. Thus, species richness may be decreasing, but because the rare species are disappearing, species evenness may be rising, resulting in no change in the value of the index. A separate calculation for richness component would be recommended, especially with the use of a richness index such as the rarefaction index. However, most of the existing measures of evenness have been criticized, with especially concise arguments being offered by Sheldon (1969), DeBendictis (1973) and Peet (1974, 1975). Edden (1971) offers an intuitively appealing measure of evenness based on the lognormal distribution. However, the difficulty of fitting a lognormal curve has already been discussed.

Stout and Vandermeer (1975), who calculated the total number of species expected at a site using species-area relationships, state "We can see no justification for computation of H or equitableness or evenness in spite of the current popularity of such computations in the ecological literature" (p. 269). I basically agree with them. Calculating the estimated total number of species at the collecting site would be the recommended approach. However, if some type of diversity index is necessary, such as for comparing single collections for which total number of species cannot be calculated, I would choose the rarefaction index primarily because of its ease of interpretation and intuitive appeal.

SUMMARY

A total of 5485 aquatic insects were collected from 37 different monotypic waterhyacinth communities in 18 Florida counties. At least 147 species of insects were identified and the identifications confirmed by experts. Aquatic insects were numerous at most sites and although the low level of dissolved oxygen (DO) beneath waterhyacinth mats has often been noted, DO-breathing forms were frequent and abundant. The most abundant families of insects were midge larvae (Chironomidae) and the burrowing water beetles (Noteridae).

The abundances of individuals in each species has biological significance since discriminant analysis distinguished the 3 repetitively sampled study sites from each other based on the abundances of the 10 most frequent insect species.

The estimated total number of species at each of the 3 study sites was approximately equal to or less than the total number of species actually collected when the species accumulation curve method was used for the estimates. Using Preston's (1948) lognormal distribution method of constructing a species abundance curve to estimate the total number of species resulted in estimates which indicated that approximately 70% of the available species actually had been collected.

Three different diversity indices were calculated with the hope that reduction of relative species abundances to a single statistic would help in determining the effects of various environmental parameters on these abundances. All 3 indices indicated a relation between increased diversity and lower values of alkalinity and the parameters strongly correlated with it. Higher levels of iron increased diversity, at least at the Camps Canal site. However, these indices were incapable of distinguishing the 3 study sites, indicating a loss of information in combining species abundance information into a single statistic. The utility of diversity indices appears to be limited. If the total number of species in the sample area cannot be estimated, the use of a diversity index to compare collections may be justified. In such a case I would recommend the rarefaction diversity index $E(S_n)$ because of its intuitive appeal, ease of interpretation and sensitivity to effects of environmental parameters.

REFERENCED CITED

Agostini, G. 1974. El genero *Eichhornia* (Pontederiaceae) in Venezuela. Acta Bot. *Venezuelica* 9(1=4):303-310.

Allan, J. David. 1975. The distributional ecology and diversity of benthic insects in Cement Creek, Colorado. Ecology 56:1040-1053.

Andres, L. A., and F. D. Bennett. 1975. Biological control of aquatic weeds. Annu. Rev. Entomol. 20:31-45.

Anonymous. 1896. Clogged by hyacinths - Navigation on the St. Johns, Florida, seriously obstructed. The Sun [newspaper], New York, Sept. 20, 1896.

Anonymous. 1966. Composite list of weeds. Weeds 14(4): 347-386.

Barber, M. A., and T. B. Hayne. 1925. Water hyacinth and the breeding of *Anopheles*. U. S. Public Health Serv. Rep. 40(47):2557-2562.

Barr, A. J., J. H. Goodnight, J. P. Sall and J. T. Helwig. 1976. A user's guide to SAS 76. SAS Institute, Raleigh, N. C. 329 pp.

Bennett, F. D. 1967. Notes on the possibility of biological control of the water hyacinth *Eichhornia crassipes*. PANS 13(4C):304-309.

Bennett, F. D. 1968a. Insects and mites as potential controlling agents of water hyacinth (*Eichhornia crassipes* (Mart.) Solms.). Proc. 9th Brit. Weed Control Conf. 832-835.

Bennett, F. D. 1968b. Investigations on insects attacking water hyacinths in Florida, British Honduras and Jamaica. C.I.B.C. Report (unpublished). 9 pp.

Bennett, F. D. 1970. Insects attacking water hyacinth in the West Indies, British Honduras and the U.S.A. Hyacinth Control J. 8(2):10-14.

Bennett, F. D. 1972. Survey and assessment of the natural enemies of water hyacinth, *Eichhornia crassipes*. PANS 18(3):310-311.

Bennett, F. D. 1974. Biological control. Pages 99-106 in D. S. Mitchell, ed. Aquatic vegetation and its use and control. UNESCO, Paris.

Bennett, F. D., and H. Zwolfer. 1968. Exploration for natural enemies of the water hyacinth in northern South America and Trinidad. Hyacinth Control J. 7:44-52.

Berner, Lewis. 1950. The mayflies of Florida. Univ. of Florida Press, Gainesville, Fla. 267 pp.

Berner, Lewis. 1968. Ephemeroptera. Pages M1-M9 in Frank K. Parrish, ed. Keys to water quality indicative organisms (Southeastern United States). Federal Water Pollution Control Admin. U. S. Dept. Agri.

Blackburn, R. D. 1974. Chemical control. Pages 85-98 in D. S. Mitchell, ed. Aquatic vegetation and its use and control. UNESCO, Paris.

Blatchley, W. S. 1914. Notes on the winter and early spring Coleoptera of Florida, with descriptions of new species. Canad. Entomologist 45:61-66, 88-92, 140-144, 247-251.

Blatchley, W. S. 1925. Notes on the distribution and habits of some Florida Coleoptera, with descriptions of new species. Canad. Entomologist 57:160-168.

Blatchley, W. S. 1932. In days agone: Notes on the fauna and flora of subtropical Florida in the days when most of its area was primeval wilderness. Nature Publ. Co., Indianapolis. 338 pp., 14 pls.

Bock, J. H. 1966. An ecological study of Eichhornia crassipes with special emphasis on its reproductive biology. Ph.D. dissertation in botany, Univ. of California. 175 pp.

Boyd, C. E., and E. Scarsbrook. 1975. Influence of nutrient additions and initial density of plants on production of waterhyacinth, Eichhornia crassipes. Aquatic Bot. 1(3):253-261.

Brillouin, L. 1960. Science and information theory. 2nd ed. Academic Press, New York. 320 pp.

Buckman, H. H. 1930. A report on an investigation of the water hyacinth for the City Commission of Jacksonville, Florida. Buckman and Co., Engineers, Jacksonville, Fla. 41 pp.

Bullock, J. A. 1971. The investigation of samples containing many species. I. Sample description. Biol. J. Linn. Soc. 3:1-21.

Burkhalter, Alva P. 1974. Aquatic weed identification and control manual. Bureau of Aquatic Plant Research and Control. Florida Dept. Natural Resources. 100 pp.

Byers, C. Francis. 1930. A contribution to the knowledge of Florida Odonata. Univ. of Florida Press, Biological Science Series, 1(1):327 pp.

Carpenter, Stanley J., and Walter J. LaCasse. 1955. Mosquitoes of North America (north of Mexico). Univ. of California Press, Berkeley. 360 pp., 127 pls.

Cason, James H. 1970. Lake Alice--A study of potential pollution of Florida aquifer. The Compass 47(4):206-210.

Center, Ted. D. 1976. Potential of *Arzama densa* (Leipdoptera: Noctuidae) for the control of waterhyacinth with special reference to the ecology of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms). Ph.D. dissertation, Univ. of Florida, Gainesville. 334 pp.

Center, Ted D., and J. K. Balciunas. 1975. The effects of water quality on the distribution of alligator weed and water hyacinth. Integrated program for alligator weed management. U. S. Army Engineer, Waterways Experiment Sta., Vicksburg, Miss. Tech. Report No. 10:B1-B13.

Chadwick, J. J., and M. Obeid. 1966. A comparative study of the growth of *Eichhornia crassipes* and *Pistia stratiotes* in water culture. J. Ecol. 54:563-575.

Chandler, Harry P. 1956. Megaloptera. Pages 229-233 *in* R. L. Usinger, ed. Aquatic insects of California. Univ. of California Press, Berkeley.

Chapman, H. C. 1958. Notes on the identity, habitat and distribution of some semi-aquatic Hemiptera of Florida. Fla. Entomol. 41(3):117-124.

Charudattan, R. 1975. Use of plant pathogens for control of aquatic weeds. Ecol. Res. Serv., U. S. E.P.A. 660-3-75-001:127-153.

Cody, Martin L., and Jaren M. Diamond. 1975. Ecology and evolution of communities. Belhnap Press of Harvard Univ. Press, Cambridge, Mass. 545 pp.

Cook, C. D. K., B. J. Gut, E. M. Rix, J. Schneller, and M. Seitz. 1974. Water plants of the world. A manual for identification of the genera of freshwater macrophytes. Dr. W. Junk b.v., Pub., The Hague. 561 pp.

Coulson, Jack R. 1971. Prognosis for control of water hyacinth by arthropods. Hyacinth Control J. 9(1):31-34.

Cuyler, R. Duncan. 1958. The larvae of *Chauliodes latreille* (Megaloptera:Corydalidae). *Ann. Entomol. Soc. Amer.* 51(6):582-586.

DeBenedictis, Paul A. 1973. On the correlations between certain diversity indices. Amer. Natur. 107(954): 295-302.

Del Fosse, Ernest S. 1975. Interaction between the waterhyacinth mite, *Orthogalumna terebrantis* Wallwork, and the mottled weevil, *Neochetina eichhorniae* Warner. Ph.D. dissertation, *Univ. of Florida, Gainesville*. 193 pp.

DeLoach, C. J. 1975. Identification and biological notes on the species of *Neochetina* that attack Pontederiaceae in Argentina. *Coleop. Bull.* 29(4):257-265.

Dymond, G. C. 1948. The water-hyacinth: a Cinderella of the plant world. Pages 221-227 *in* J. P. J. Van Vurens, ed. Soil fertility and sewage. Faber and Faber, Ltd., London.

Edden, A. C. 1971. A measure of species diversity related to the lognormal distribution of individuals among species. J. Exper. Mar. Biol. Ecol. 6:199-209.

Fager, E. W. 1972. Diversity: a sampling study. Amer. Natur. 106(949):293-310.

Ferguson, Frederick F. 1968. Aquatic weeds and man's well-being. Hyacinth Control J. 7:7-11.

Freeman, T. E., F. W. Zettler and R. Charudattan. 1974. Phytopathogens as biocontrols for aquatic weeds. PANS 20(2):181-184.

Goin, C. J. 1943. The lower vertebrate fauna of the water hyacinth community in northern Florida. Proc. Fla. Acad. Sci. 6(3-4):143-153.

Good, I. J. 1953. The population frequencies of species and the estimation of population parameters. *Biometrika* 40:237-264.

Gordon, Robert D., and J. R. Coulson. 1969. Report on field observations of arthropods on water hyacinth in Fla., La., Tex. Aquatic Plants Control Prog., U. S. Army Engineer, Vicksburg, Miss. Tech. Rep. 6:B3-B37.

Gowanloch, James Nelson. 1944. The economic status of the water hyacinth in Louisiana. La. Conservationist 2: 3, 6, 8.

Green, Roger H. 1971. A multivariate statistical approach to the Hutchinsonian niche: bivalve mulluscs of Central Canada. Ecology 52(4):543-556.

Haller, William T., and D. L. Sutton. 1973. Effect of pH and high phosphorus concentrations on growth of water-hyacinth. Hyacinth Control J. 11:59-61.

Haller, W. T., E. B. Knipling and S. H. West. 1970. Phosphorous absorption by and distribution in water hyacinths. Proc. Fla. Soil and Crop Sci. Soc. 30:65-68.

Hansen, K. L., E. G. Ruby and R. L. Thompson. 1971. Trophic relationships in the water hyacinth community. Quart. J. Fla. Acad. Sci. 34(2):107-113.

Heck, K. L., Jr., G. van Belle and D. Simberloff. 1975. Explicit calculation of the rarefaction diversity measurement and the determination of sufficient sample size. Ecology 56:1459-1461.

Herring, Jon L. 1948. Taxonomic and distributional notes on the Hydrometridae of Florida (Hemiptera). Fla. Entomol. 31(4):112-116.

Herring, Jon L. 1950a. The aquatic and semiaquatic Hemiptera of northern Florida. Part 1. Gerridae. Fla. Entomol. 33(1):23-32.

Herring, Jon L. 1950b. The aquatic and semiaquatic Hemiptera of northern Florida. Part 2: Veliidae and Mesoveliidae. Fla. Entomol. 33(4):145-150.

Herring, Jon L. 1951a. The aquatic and semiaquatic Hemiptera of northern Florida. Part 3: Nepidae, Belostomatidae, Notonectidae, Pleidae and Corixidae. Fla. Entomol. 34(1):17-29.

Herring, Jon L. 1951b. The aquatic and semiaquatic Hemiptera of northern Florida. Part 4: Classification of habitats and keys to the species. Fla. Entomol. 34(4):146-161.

Hitchcock, A. E., P. W. Zimmerman, H. Kirkpatrick, Jr. and T. T. Earle. 1949. Water hyacinth: its growth, reproduction and practical control by 2,4-D. Contrib. Boyce Thompson Inst. 15(7):363-401.

Hitchcock, A. E., P. W. Zimmerman, H. Kirkpatrick, Jr., and T. T. Earle. 1950. Growth and reproduction of water hyacinth and alligator weed and their control by means of 2,4-D. Contrib. Boyce Thompson Inst. 16(3):91-130.

Holm, L. G., L. W. Weldon, and R. D. Blackburn. 1969. Aquatic weeds. Science 166:699-709.

Horn, G. H. 1880. Synopsis of the Dascyllidae of the United States. Trans. Amer. Entomol. Soc. 8:76-114.

Hurlbert, Stuart H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 54:577-585.

Ingersoll, Jean M. 1964. Historical examples of ecological disaster: The water hyacinth; the copper basin. Office of Civil Defense, Dept. of Defense, Report HI-360-RR/A1-2.

Johnson, Clifford, and Minter J. Westfall, Jr. 1970. Diagnostic keys and notes on the damselflies (Zygoptera) of Florida. Bull. Fla. State Mus. 15(2):45-89.

Katz, Edith E. 1967. Effects of the chemical eradication of water hyacinths on associated aquatic fauna. M.S. thesis, Stetson Univ., Deland, Fla. 52 pp.

Kelsey, H. P., and W. A. Dayton. 1942. Standardized plant names. J. Horace McFarland Co., Harrisburg, Pennsylvania. 675 pp.

Klorer, J. 1909. The water hyacinth problem. J. Assoc. Eng. Soc. 42:33-48.

Knipling, E. B., S. H. West and W. T. Haller. 1970. Growth characteristics, yield potential, and nutritive content of water hyacinths. Proc. Fla. Soil and Crop Sci. 30: 51-63.

La Rivers, Ira. 1948. A new species of Pelocoris from Nevada, with notes on the genus in the United States. Ann. Entomol. Soc. Amer. 41:371-376.

La Rivers, Ira. 1970. A new species of Pelocoris femoratus (Palisot-Beauvois) from Florida (Hemiptera:Naucoridae). Biol. Soc. Nev. Occas. Papers 26:1-4.

Leech, H. B., and H. P. Chandler. 1956. Aquatic Coleoptera. Chap. 13 in R. L. Usinger, ed. Aquatic insects of California. Univ. California Press, Berkeley.

Lynch, J. J., J. E. King, T. K. Chamberlain, and A. L. Smith, Jr. 1947. Effects of aquatic weed infestations on the fish and wildlife of the Gulf states. U. S. Dept. Interior, Fish/Wildlife Serv., Special Sci. Report No. 39.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press, Princeton, N. J. 204 pp.

Margalef, R. 1969. Diversity and stability: a practical proposal and a model of interdependence. Brookhaven Symp. Biol. 22:25-37.

May, Robert M. 1975. Patterns of species abundance and diversity. In, M. L. Cody and J. M. Diamond, eds. Ecology and evolution of communities. Belknap Press of Harvard Univ, Press, Cambridge, Mass.

McFadden, Max W. 1967. Soldier fly larvae in America north of Mexico. Proc. U. S. Nat. Mus. 121(3569):1-62.

McIntosh, Robert P. 1967. An index of diversity and the relation of certain concepts to diversity. Ecology 48(3):392-404.

Mitchell, D. S. 1974. Aquatic vegetation and its use and control. UNESCO, Paris. 135 pp.

Monk, C. D. 1967. Tree species diversity in the eastern deciduous forest with particular reference to north central Florida. Am. Natur. 101:173-187.

Montgomery, B. E. 1944. The distribution and relative seasonal abundance of the Indiana species of Agrionidae. Proc. Ind. Acad. Sci. 51:273-278.

Morris, R. F. 1960. Sampling insect populations. Annu. Rev. Entomol. 5:243-264.

Morris, Thomas L. 1974. Water hyacinth Eichhornia crassipes (Mart.) Solms: Its ability to invade aquatic ecosystems of Payne's Prairie Preserve. M.S. thesis, Univ. of Florida, Gainesville. 135 pp.

Morrison, Donald F. 1967. Multivariate statistical methods. McGraw-Hill, New York.

Muenscher, W. C. 1967. Aquatic plants of the United States. Comstock Publ. Co., Inc., Ithaca, New York. 374 pp.

Mulrennan, John A. 1962. The relationship of mosquito breeding to plant production. Hyacinth Control J. 1:6-7.

Needham, J. C., and M. J. Westfall, Jr. 1955. A manual of the dragonflies of North America (Anisoptera) including the Greater Antilles and the provinces of the Mexican border. Univ. California Press, Berkeley. 615 pp.

O'Hara, James. 1961. The invertebrate fauna associated with water hyacinths in South Florida. M.S. thesis, Univ. Miami, Florida. 66 pp.

O'Hara, James. 1968. Invertebrates found in water hyacinth mats. Quart. J. Fla. Acad. Sci. 30(1):73-80.

Patrick, R. 1954. Diatoms as indication of river change. Proc. Ind. Waste Conf. 9th, Purdue Univ. Eng. Exten. Serv. 87:325-330.

Peet, Robert K. 1974. The measurement of species diversity. Annu. Rev. Ecol. and Syst. 5:285-307.

Peet, Robert K. 1975. Relative diversity indices. Ecology 56:496-498.

Penfound, W. T., and T. T. Earle. 1948. The biology of the water hyacinth. Ecol. Monog. 18:447-472.

Pennak, Robert W. 1953. Fresh-water invertebrates of the United States. Ronald Press Co., New York. 769 pp.

Perkins, B. D. 1972. Potential for waterhyacinth management with biological agents. Proc. Annu. Tall Timbers Conf. on Ecol. Anim. Control by Habitat Management, Feb. 24-25, 1972:53-64.

Perkins, B. D. 1973. Preliminary studies of a strain of the waterhyacinth mite from Argentian. C.I.B.C. Misc. Publ. 6:179-184.

Perkins, B. D. 1974. Arthropods that stress waterhyacinth. PANS 29(3):304-314.

Pielou, E. C. 1966a. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13:131-144.

Pielou, E. C. 1966b. Shannon's formula as a measure of species diversity: its use and misuse. Amer. Natur. 100:463-465.

Pielou, E. C. 1969. An introduction to mathematical ecology. Willey-Interscience, New York. 286 pp.

Pieterse, A. H. 1974. The water hyacinth. Trop. Abstr. 29(2):X263-X483.

Poole, R. W. 1974. An intorduction to quantitative ecology. McGraw, New York. 532 pp.

Preston, F. W. 1948. The commonness, and rarity, of species. Ecology 29(3):254-283.

Preston, F. W. 1958. Analysis of the Audobon Christmas counts in terms of the lognormal curve. Ecology 39(4): 620-624.

Preston, F. W. 1962. The canonical distribution of commonness and rarity. Ecology 43:185-215, 410-432.

Price, Peter W. 1975. Insect ecology. John Wiley and Sons, New York. 514 pp.

Raynes, J. J. 1964. Aquatic plant control. Hyacinth Control J. 3:2-4.

Robson, T. O. 1974. Mechanical control. Pages 72-84 in D. S. Mitchell, ed. Aquatic vegetation and its use and control. UNESCO, Paris.

Sager, P. E., and A. D. Hasler. 1969. Species diversity in lacustrine phytoplankton. I. The components of the index of diversity from Shannon's formula. Amer. Natur. 103:51-59.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. Amer. Natur. 102:243-282.

Seabrook, E. L. 1962. The correlation of mosquito breeding to hyacinth plants. Hyacinth Control J. 1:18-19.

Sheldon, Andrew L. 1969. Equitability indices: dependence on the species count. Ecology 50:466-467.

Simberloff, D. 1972. Properties of the rarefaction diversity measurement. Amer. Natur. 106:414-418.

Simpson, E. H. 1949. Measurement of diversity. Nature 163: 688.

Small, J. K. 1933. Manual of the southeastern flora. Univ. North Carolina Press, Chapel Hill. 1554 pp.

Spencer, N. R. 1973. Insect enemies of aquatic weeds. Proc. 3rd Int. Symp. Biol. Control of Weeds: 39-47.

Spencer, N. R. 1974. Insect enemies of aquatic weeds. PANS 20(4):444-450.

Stimac, J. L., and K. L. Leong. 1977. Factors affecting chironomid larval abundances in three vertical aquatic weed habitats. Environ. Entomol. 6(4):595-600.

Stodola, Jiri. 1967. Encyclopedia of water plants. T. F. H. Publications, Jersey City, New Jersey. 368 pp.

Stout, Jean, and John Vandermeer. 1975. Comparison of species richness for stream-inhabiting insects in tropical and mid-latitude streams. Amer. Natur. 109(967):263-280.

Strong, Donald R., Jr. 1974a. The insects of British trees: Community equilibration in ecological time. Ann. Missouri Bot. Gard. 61:692-701.

Strong, Donald R., Jr. 1974b. Rapid asymptotic species accumulation in phytophagous insect communities: the pests of cacao. Science 185:1064-1966.

Sutton, D. L., and R. D. Blackburn. 1971a. Uptake of copper by water hyacinth. Hyacinth Control J. 9(1):18-20.

Sutton, D. L., and R. D. Blackburn. 1971b. Uptake of copper by parrotfeather and water hyacinth. Proc. 24th Annu. S. Weed Sci. Soc.: 331.

Tabita, Angelo, and John W. Woods. 1962. History of hyacinth control in Florida. Hyacinth Control J. 1:19-23.

Tilghman, Noah J. 1962. The value of water hyacinth in the propogation of fish. Hyacinth Control J. 1:8.

Ultsch, Gordon R. 1971. The relationship of dissolved carbon dioxide and oxygen to microhabitat selection in Pseudobranchus striatus. Copeia 1971(2):247-252.

Ultsch, Gordon R. 1973. The effects of water hyacinths on the microenvironment of aquatic communities. Arch. Hydrobiol. 72(4):460-473.

Usinger, R. L., ed. 1956. Aquatic insects of California. Univ. California Press, Berkeley. 508 pp.

van Emden, H. F., and G. F. Williams. 1974. Insect stability and diversity in agro-ecosystems. Annu. Rev. Entomol. 19:455-475.

Viosca. Percy, Jr. 1924. Report of the entomologist. Page 43 in Annual report of the Board of Health, Parish of New Orleans and the City of New Orleans.

Wahlquist, Harold. 1969. Effect of water hyacinths and fertilization on fish-food organisms and production of bluegill and redear sunfish in experimental ponds. Proc. 23rd Annu. Conf. Southeastern Assoc. Game and Fish Commrs: 373-384.

Wahlquist, Harold. 1972. Production of waterhyacinths and resulting water quality in earthen ponds. Hyacinth Control J. 10:9-11.

Wakefield, John W., and William M. Beck, Jr. 1962. Effects of water pollution on aquatic vegetation. Hyacinth Control J. 1:10.

Walker, Edmund M. 1953. The Odonata of Canada and Alaska, Vol. 1, Part 1, General Part II, The Zygoptera--damselflies. Univ. Toronto Press. 292 pp.

Wallace, J. B. 1968. Trichoptera. Pages S1-S19 *in* Frank K. Parrish, ed. Keys to water quality indicative organisms (Southeastern United States). Fed. Water Pollution Control Admin. U. S. Dept. Agric.

Webber, H. J. 1897. The water hyacinth and its relation to navigation in Florida. U. S. Dept. Agric. Bull. 18:1-20.

Weber, Hans. 1950. Morphologische und anatomische Studien uber *Eichhornia crassipes* (Mart.) Solms. Abhandlunger der Mathematisch-Naturwisserschaftlicher Klasse. Academie der Wissenshaften und div Literature. Mainz. 1950(6):135-161.

Westfall, Minter J., Jr. 1957. A new species of *Telebasis* from Florida (Odonata:Zygoptera). Fla. Entomol. 40(1): 19-24.

Westlake. D. F. 1963. Comparisons of plant productivity. Biol. Rev. 38:385-425.

Whittaker, R. H. 1965. Dominance and diversity in land plant communities. Science 147:250-260.

Whittaker, R. H. 1972. Evolution and measurement of species diversity. Taxon 21:213-251.

Wilhm, Jerry L., and Troy C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18(6): 477-481.

Wilhm, Jerry L. 1972. Graphic and mathematical analyses of biotic communities in polluted streams. Annu. Rev. Entomol. 17:223-252.

Williams, C. B. 1964. Patterns in the balance of nature. Academic Press, London. 324 pp.

Wirth, Willis W., and Alan Stone. 1956. Aquatic Diptera. Chapter 14 *in* R. L. Usinger, ed. Aquatic insects of California. Univ. California Press, Berkeley.

Wright, Mike, and Alvan Peterson. 1944. A key to the genera of anisopterous dragonfly nymphs of the United States and Canada (Odonata, suborder Anisoptera). Ohio J. Sci. 44(4):151-166.

Young, Frank N. 1954. The water beetles of Florida. Univ. Florida Press, Gainesville. 238 pp.

Young, Frank N. 1955. The type locality and habitat of Hydroporus dixianus Fall (Coleoptera:Dytiscidae). Coleop. Bull. 9(1):7-9.

Young, Frank N. 1956. A preliminary key to the species of Hydrovatus of the eastern United States (Coleoptera: Dytiscidae). Coleop. Bull. 10(3):53-54.

Young, Frank N. 1961. Pseudosibling species in the genus Peltodytes (Coleoptera:Haliplidae). Ann. Entomol. Soc. Amer. 54(2):214-222.

Young, Frank N. 1963. Two new North American species of Hydrovatus with notes on other species (Coleoptera: Dytiscidae). Psyche 70(3):184-192.

Zeiger, Charles F. 1962. Hyacinth--obstruction to navigation. Hyacinth Control J. 1:16-17.

Zettler, F. W., and T. E. Freeman. 1972. Plant pathogens as biocontrols of aquatic weeds. Annu. Rev. Phytopathol. 10:455-470.

APPENDIX A

Fortran program for Shannon's and Simpson's diversity indices (and Brillouin's, when possible).

```
C      SHANNON-WEAVER DIVERSITY INDEX  AND  SIMPSON'S DIVERSITY INDEX
C       (ALSO BRILLOIN'S INDEX FOR NTOT<69 )
C
*CUTOFF=5
       DIMENSION N(1000),NF(1000)
 1     READ,COLLNO,NTOT,SPECIES
       T=NTOT
       K=SPECIES
       SUM=0
       READ,(N(I),I=1,K)
       I=1
       DO 8 M=1,K
       SUM=SUM+N(I)
       I=I+1
 8     CONTINUE
       IF(SUM.EQ.T)GO TO 20
       WRITE(6,21)
 21    FORMAT('VALUE OF TOTAL NUMBER OF SPECIMENS INCORRECT')
       PRINT,SUM
       GO TO 1
  20   PRINT,COLLNO,NTOT,SPECIES
       PRINT,(N(I),I=1,K)
       J=1
       I=1
       SUM=0
       DO 12 M=1,K
       SUM=SUM+N(I)*(N(I)-1)
       I=I+1
 12    CONTINUE
       D=1-SUM/(T*(T-1))
       SUM=0
       I=1
       DO 10 M=1,K
       P=N(I)/T
       SUM=P*ALOG(P)+SUM
       I=I+1
 10    CONTINUE
       HS=-SUM
       J=1
       M=1
       I=1
       TF=T
 2     TF=TF*(T-J)
       J=J+1
       IF(T-J)3,3,2
 3     NF(I)=N(I)
       IF(N(I)-1)16,16,17
 16    NF(I)=1
       GO TO 5
 17    J=1
 4     NF(I)=NF(I)*(N(I)-J)
       J=J+1
       IF (N(I)-J)5,5,4
 5     I=I+1
       IF(I.LE.K)GO TO 3
       PROD=1
       I=1
       DO 11 M=1,K
       PROD=PROD*NF(I)
       I=I+1
 11    CONTINUE
       NSKIP=0
       IF((TF/PROD).LT.NSKIP) GO TO 100
       HB=(1/T)*(ALOG(TF/PROD))
       PRINT,HS,HB,D
  96   DO 97 I=1,4
        WRITE(6,99)
 99     FORMAT('   ')
  97    CONTINUE
        GO TO 1
  100  PRINT,HS,NSKIP,D
       GO TO 96
END OF WORK FILE
```

APPENDIX B

Fortran program for rarefaction diversity index.

```
C         RAREFACTION DIVERSITY INDEX
$CUI IFF=2
          DIMENSION AFAC(500),NN(500),NU(500),T(500),P(500)
          DO 10 I=1,499
          AFAC(1)=0
10        AFAC(I+1)=AFAC(I)+ALOG(FLOAT(I+1))
81        READ,COLLNO,N,NS,MAX
          PRINT,COLLNO,N,NS,MAX
          READ,(NU(J),J=1,MAX)
          NCHK=0
          DO 99 J=1,MAX
          NCHK=NCHK+NU(J)*J
99        CONTINUE
          IF(NCHK.NE.N)GO TO 98
          K9=1
          DO 390 J=1,MAX
385       IF(NU(J).EQ.0)GO TO 390
          NN(K9)=J
          NU(J)=NU(J)-1
             K9=K9+1
             GO TO 385
390       CONTINUE
8         READ,M
          IF(M.EQ.0)GO TO 81
          IF(M.EQ.1)GO TO 15
          VAR=0.
          SM=0.
          DO 11 I=1,NS
          NNI=NN(I)
          IF(N-NNI-M.LE.0)GO TO 11
          T(I)=AFAC(N-NNI)-AFAC(N-NNI-M)+AFAC(N-M)-AFAC(N)
          P(I)=EXP(T(I))
          SM=SM+P(I)
          VAR=VAR+P(I)*(1-P(I))
11        CONTINUE
          DO 13 I=1,NS
          IF(NS-I.LE.0)GO TO 13
          K=I+1
          DO 13 J=K,NS
          NNI=NN(I)
           NNJ=NN(J)
          FIJ=0.
          IF(N-NNI-NNJ-M.LE.0)GO TO 13
          FIJ=AFAC(N-NNI-NNJ)-AFAC(N-NNI-NNJ-M)+AFAC(N-M)-AFAC(N)
          PIJ=EXP(FIJ)
          VAR=VAR+2.*(PIJ-P(I)*P(J))
13        CONTINUE
          ANS=NS
          SD=SQRT(VAR)
          SM=ANS-SM
          WRITE(6,3)M,SM,SD,VAR
3         FORMAT(1X,I5,2X,3F10.4)
          GO TO 8
15        CONTINUE
          STOP
98        WRITE(6,97)
97        FORMAT('NUMBER OF SPECIMENS IS IN ERROR')
          PRINT,NCHK
          GO TO 81
          END
END OF WORK FILE
```

BIOGRAPHICAL SKETCH

Juozas (Joseph) Kestutis Balciunas was born 3 October 1946 at Wurtzbürg, Bavaria, Germany. The son of Drs. Jurgis and Brone Balciunas, he emigrated to the United States in 1950 and became a naturalized citizen in 1960.

Upon graduation from St. Joseph's High School, Dover, Ohio, in 1964, he entered John Carroll University, Cleveland, Ohio, where, in 1969, he received his Bachelor of Science in biology with a minor in chemistry. He then accepted a teaching assistantship in the Biology Department at John Carroll University and received his Master of Science degree in biology in 1972. His Master's project involved the distribution of odonate nymphs in an Ohio county.

In August of 1971 he accepted a research assistantship at the University of Florida, where he is currently fulfilling the requirements for the degree of Doctor of Philosophy. His dissertation project involves the abundance and diversity of aquatic insect species found beneath waterhyacinths.

Joseph K. Balciunas is single. He is a member of the Ecological Society of America and the Florida Entomological Society.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dale H Habeck

Dale H. Habeck, Chairman
Professor of Entomology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Archie F. Carr
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December 1977

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