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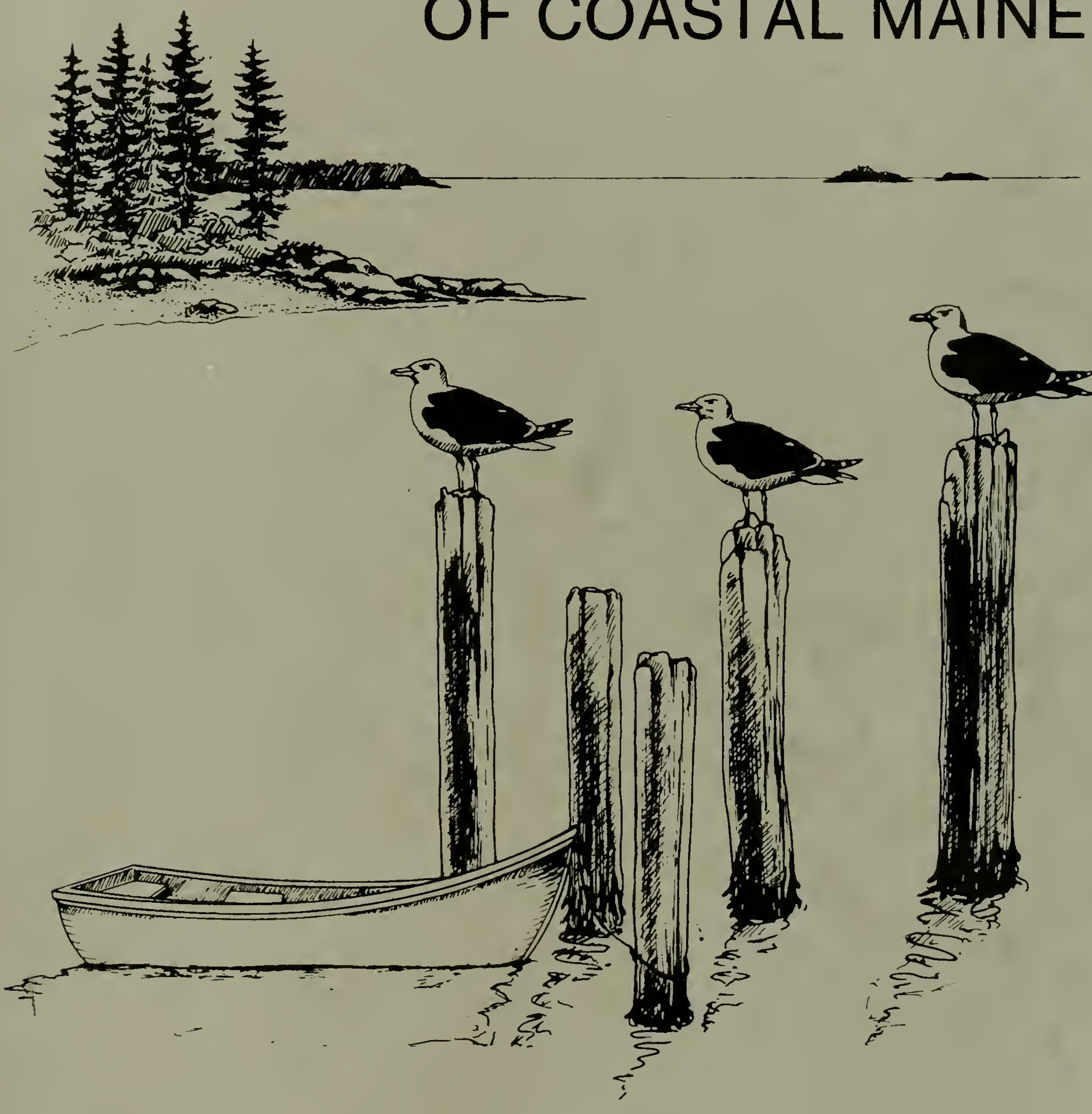
AN ECOLOGICAL CHARACTERIZATION OF COASTAL MAINE



Fish and Wildlife Service

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AN ECOLOGICAL CHARACTERIZATION OF COASTAL MAINE
(North and East of Cape Elizabeth)

Stewart I. Fefer and Patricia A. Schettig
Principal Investigators

Volume 3

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U.S. Fish and Wildlife Service
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TABLE OF CONTENTS

Volume 1

Volume 2

Volume 3

Chapter 16 (Continued)

LIST OF FIGURES

LIST OF TABLES

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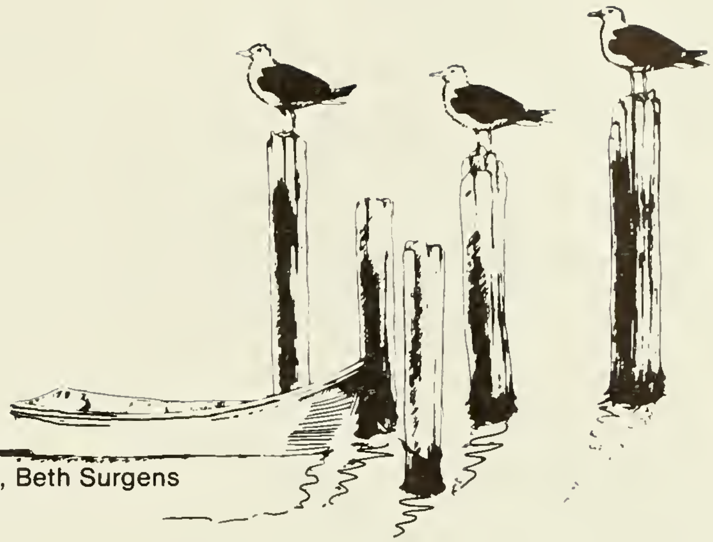

Chapter 11 Fishes

Authors: Patricia Shettig, Stanley Chenoweth, Beth Surgens

Over 100 species of fishes, representing 40 families, inhabit the marine, estuarine, and freshwater systems of coastal Maine. The majority are resident species, and many have commercial and recreational value. Fishes are both predators and prey in aquatic food chains and play an important role in energy flow within aquatic systems because of their great abundance at different trophic levels.

Fishes generally can be classified into two major categories: pelagic and demersal. Pelagic fishes (e.g., herrings, mackerel, and striped bass) are highly mobile and range freely throughout the water column. They feed mostly on plankton and other pelagic organisms. Demersal fishes (e.g., flounders, sculpins, and cod) are less mobile and usually stay on or near the bottom. These fishes feed mostly on benthic invertebrates and other bottom fishes. Freshwater fishes, for the most part, are semidemersal in habit. Because most marine and estuarine fishes are highly mobile, geographic and habitat preferences are difficult to identify.

The habitat and food requirements of most fishes vary according to the life stage of the fish. If fish resources are to be managed effectively the environmental requirements of species or groups of species at each life stage of the fish must be understood. Unfortunately, very few of these requirements are known.

This chapter discusses the status and distribution of fish species in coastal Maine habitats and systems and the factors that influence their distribution and abundance. Marine and estuarine fishes are emphasized. Natural factors that affect the distribution and abundance of fishes include salinity, temperature, food availability, streamflow and cover, competition, predation, and disease. Water pollution, barriers to migration, and overharvesting (overfishing and selective fishing) are the most severe limiting factors to fish populations in coastal Maine.

Fish populations are important ecologically and as a renewable commercial and recreational natural resource. For many species the management of fisheries on a single species basis has not been entirely successful. The existing structure and process for management of the fishery resources is discussed in this chapter under "Management." Research priorities and additional data are identified under "Research Priorities." The consumer role of fishes in aquatic food webs is discussed further in "The Marine System," chapter 4; "The Estuarine System," chapter 5; "The Riverine System," chapter 6; "The Lacustrine System," chapter 7; and "The Palustrine System," chapter 8. Relevant fish distributional data are given in atlas map 4. The corresponding scientific names of all common names of fishes mentioned in the text are found in the appendix to chapter 1. A brief life history of the shortnose sturgeon, a Federally listed endangered species, is given.

DATA SOURCES

Most of the information on the distribution of coastal marine and estuarine fishes in this chapter comes from Chenoweth (unpublished), The Research Institute of the Gulf of Maine (TRIGOM; 1974), Maine Yankee Atomic Power Company surveys (1970 to 1976), Central Maine Power Company (1974 to 1975), Tyler (1971), and MacKay and coworkers (1978). Detailed data from these surveys covers the Boothbay region (lower Sheepscot and Damariscotta Rivers), the Sheepscot River-Montsweag Bay area, Penobscot Bay (near Sears Island), central Passamaquoddy Bay and the Deer Isle/Campobello Island area. Complete lists of species found in these surveys are provided in appendix tables 1 to 7.

Ongoing surveys that have provided and will continue to provide data on the seasonal distribution of groundfish along the Maine coast are: National Marine Fisheries Service (NMFS) Groundfish Survey Program, and Maine Department of Marine Resources (MDMR) Inshore Groundfish Survey Program which began in spring 1979. The NMFS Fishery Research Center in Woods Hole, Massachusetts, also provided extensive data on the food habits of important Atlantic marine fishes. General distribution, life history, and behavioral information on Gulf of Maine fishes was acquired from Bigelow and Schroeder (1953), Clayton and coworkers (1976), Scott and Messieh (1976), and Leim and Scott (1966). Data on the distribution of inshore, freshwater fishes was provided by Maine Department of Inland Fisheries and Wildlife (MDIFW). Fish life history information was obtained from Scott and Crossman (1973), Everhart (1958), and Scarola (1973).

THE MAJOR FISHES OF COASTAL MAINE

Many fishes of coastal Maine are of commercial and sport value and some are important ecologically because of their role in the food chain or their scientific interest. The major fishes of coastal Maine and their primary realms of importance are listed in table 11-1.

The gadids are members of the cod family and are principally marine bottom fishes. (The burbot is a freshwater gadid.) They include Atlantic cod, haddock, the hakes (red, white, and silver), American pollock, and Atlantic tomcod. All but the tomcod are fished commercially. These species contributed over 28 million pounds of the total Maine landings in 1977 (Lewis 1979). The hakes are important summer migrants to Maine waters; the other

Table 11-1. The Major Fishes of Coastal Maine and Their Primary Realms of Importance.

Species	Catagory		
	Commercial	Sport	Ecological
Gadids			
Atlantic cod	X	X	
Haddock	X		
Hakes (red, white, and silver)	X		
American pollock	X		
Atlantic tomcod			X
Skates			
Little, winter, and thorny			X
Herrings			
Atlantic herring	X		X
Atlantic menhaden	X		X
American sand lance			X
Redfish	X	X	
Atlantic mackerel	X	X	
Sculpins			X
Rock gunnel			X
Flounders			
Winter flounder	X	X	
American plaice	X		X
Yellowtail- and witch flounder	X		
Smooth flounder and windowpane			X
Anadromous and catadromous Fishes			
Alewife	X	X	X
Atlantic salmon		X	
American shad		X	
Blueback herring	X		X
American eel	X		X
Rainbow smelt		X	X
Atlantic sturgeon			X
Shortnose sturgeon			X
Striped bass	X	X	
Freshwater fishes			
Trout(brook, brown, lake, and rainbow)		X	
Smallmouth- and largemouth bass		X	
White perch		X	
Yellow perch		X	X
Chain pickerel		X	
Minnows			X
White sucker			X
Brown bullhead			X

gadids are resident year-round. The tomcod is more common in estuaries than the other gadids.

The skates, also resident marine bottom fishes, are stingray-like in appearance and are very abundant along coastal Maine. The winter skate, little skate, and thorny skate are common in the shallow, cool waters along the coast. The skates are of little commercial importance, although some may be used as bait (Thomson et al. 1971).

The Atlantic herring is the most important commercial finfish in Maine waters. Juvenile herring support the sardine industry. Atlantic herring are pelagic fish usually found in groups of hundreds or thousands. They are common inshore and in bays and estuaries during summer months, and spend winter months offshore. These fish are important prey for other fishes, birds, and marine mammals. Herring are caught inshore by purse seine and in weirs. The Atlantic menhaden is a large schooling fish of the herring family whose commercial landings in Maine fluctuate widely (ranging from 3 million to 18 million pounds between 1973 and 1977). Their northern range extends in the Gulf of Maine during summer months but they are not known to spawn there.

The American sand lance is a small schooling fish found in shallow sandy bottoms along the coast and out to the continental shelf. Sand lances are extremely numerous and are important ecologically as food for larger fishes, marine mammals, and seabirds.

The redfish is an important commercial resource in Maine, contributing over 20 million pounds to Maine landings in 1977. A northern fish, the redfish prefers the deeper, colder waters of the Gulf of Maine. It is plentiful, also, in nearshore deep water areas (e.g., eastern Maine).

The Atlantic mackerel migrates to coastal Maine in summer, moving in response to seasonal changes in temperature. The mackerel is an important commercial fish and supports a summer recreational fishery in Maine. Most mackerels leave the coast in late autumn and winter in offshore waters.

The sculpins (Cottidae) are ubiquitous resident bottom fishes, found in shallow marine and estuarine waters along the coast. Sculpin include the sea raven, grubby, shorthorn sculpin, and longhorn sculpin. Because they are abundant and bottom-dwelling, sculpin are an important part of benthic food webs. The sea raven, shorthorn sculpin, and longhorn sculpin are of minor commercial importance as baitfish in the lobster fishery.

The rock gunnel is one of the most abundant fishes along the coast, common in tide pools and rocky areas. It is eaten by cod and pollock but much of its role in coastal ecology is unknown (Clayton et al. 1976).

Flounders are one of the major inshore groundfishes. The winter flounder is the most common, found from inland areas of estuaries to Georges Bank (TRIGOM 1974). This species is an important commercial and sport fish. The American plaice is probably the most numerically dominant flounder in nearshore coastal waters (personal communication from S. Chenoweth, Maine Department of Marine Resources, Augusta, ME; December 1979). The plaice is also a major commercial groundfish. The witch flounder and yellowtail flounder are important commercial resources. Witch flounder populations are centered north of Cape

Cod, while the yellowtail flounders are more abundant in southern New England waters. Neither are very common in estuaries. The smooth flounder and windowpane are common in bays and estuaries. Neither are sought commercially.

The anadromous and catadromous fishes are an important resource in coastal Maine. Anadromous fishes are those that migrate up rivers from the sea to spawn in fresh or brackish waters. Catadromous fishes migrate down rivers to the sea to spawn. Many support commercial and sport fisheries; others are important ecologically. These fishes are of special interest because of their history. Maine's historically rich populations of anadromous fishes were nearly destroyed by harmful uses of dams and barriers but careful management since the 1960s has partially restored them. Based on its distribution, abundance, role in aquatic systems, and many commercial uses, the alewife may be the most important anadromous fish in Maine. Once an important staple in the diet of New England settlers (Clayton et al. 1976), the species is the primary one being restored by the Maine Department of Marine Resources Anadromous Fish Program. Alewives are the most numerous among the fishes that migrate up coastal streams and rivers. The alewife is an important forage fish, providing food for many game fishes (e.g., striped bass, bluefish, and some trouts), seals, waterfowl, and for the osprey and bald eagle. Commercially, alewives are used extensively for fish meal in fertilizers and animal foods. They have another important use as bait for lobster traps and trawl fisheries. The primary alewife fishery is carried out during the upstream spawning migration of adults. The blueback herring is very similar to the alewife in appearance and habit but the blueback is a summer migrant to coastal Maine, is less abundant than the alewife, and begins its spawning run later. Blueback herring are caught and processed commercially and used as lobster bait indiscriminantly from alewives.

The Atlantic salmon is a highly prized sport fish of special interest in Maine and New England. Its population in coastal Maine is currently reduced, largely as a result of dams constructed along streams used by salmon for upstream migration. Of all the North Atlantic rivers where salmon have ranged historically, only a few rivers (e.g., the Dennys) in Maine support natural reproduction of Atlantic salmon. The plight of the salmon is well known, and its recovery is a focus of State and Federal agencies.

Like the Atlantic salmon, American shad populations have suffered greatly at the expense of industrialization, dam construction, and pollution. The shad once supported a significant commercial fishery but its distribution is now limited to probably 4 or 5 stream systems in Maine. A shad restoration/stocking program is currently underway in the Royal River (personal communication from T. Squires, Maine Department of Marine Resources, Augusta, ME; December, 1979).

The rainbow smelt is very common in streams, estuaries, and landlocked lakes along the coast. The smelt is important as a forage fish, constituting the most important single food item of Maine's landlocked Atlantic salmon (Everhart 1958). Smelt are an important recreational resource. They are taken with hook and line, or caught by hand or dipnet during the upstream spawning run. Smelt are often fished from ice shanties on frozen bays and estuaries in winter. They are also a highly valuable bait species.

The only sturgeons found in Maine are the Atlantic sturgeon and the shortnose sturgeon. Neither are very numerous, and the shortnose sturgeon is listed by the Federal Government as an endangered species (see "Shortnose Sturgeon" section in this chapter). Both sturgeons are sluggish, slow swimming, bottom fishes that are hampered by dams and obstructions in streams. These sturgeons once supported a commercial market. Their roe is well known commercially as caviar.

The American eel, the only catadromous fish in Maine, spends its early life upstream in fresh water and migrates down to the sea to spawn. Young eel (elvers) swim upstream in spring of the following year. The eel is an important commercial resource for food and bait. The extensive migrations of eels and the locations of their spawning areas are not well documented. It is known they spawn in the Sargasso Sea area rather than the Gulf of Maine.

The striped bass is one of the most popular marine sport fishes in Maine and New England. It is a summer migrant to waters north of Cape Cod, appearing regularly in bays and estuaries, but evidence of its spawning in Maine has not been found in many years (Bigelow and Schroeder 1953).

The major freshwater fishes have sport or ecological importance. The brook trout, brown trout, lake trout, rainbow trout, landlocked Atlantic salmon, chain pickerel, white perch, yellow perch, smallmouth bass and largemouth bass are the major freshwater sport fishes. Minnows are small freshwater fish in the family Cyprinidae. They are usually abundant because they occupy a variety of habitats and utilize many food types, and a large number can occupy a small area (Everhart 1958). The golden shiner and fallfish are the most widely distributed minnows in the coastal zone. Minnows are important because of their position in the food chain. They serve as forage for many desirable food and sport fishes. One minnow (carp) has posed a problem in many states. The carp was introduced into the United States as a potential commercial fish. Through improper handling, this large fish has spread and proliferated in all types of fresh waters, competing with more desirable fishes for food and space. In addition, carp feeding behavior disturbs habitats by stirring up mud and sediments and uprooting aquatic plants while feeding. Carp control is of great concern to fishery managers.

The white sucker is the most abundant and most common of the larger fishes in the lakes and tributary streams. They are bottom fish and serve as forage for many game fishes until they become too large for the game fishes to swallow. Large suckers may then compete with more commercially and recreationally desirable fishes. The brown bullhead, or hornpout, is the only member of the catfish family found in Maine and is widely distributed in the coastal zone.

DISTRIBUTION

Cape Cod represents a major biological and physical barrier separating populations of Atlantic fishes in the Gulf of Maine from those of the mid-Atlantic Bight (Colton et al. 1979). Coastal Maine waters are characterized by stable, resident populations of mostly boreal (northern) fish species, with some migratory populations of temperate species from the south and occasionally some subarctic species from the northeast. Reflective of the area's physiography, coastal fish populations are dominated by demersal marine and estuarine species. Data from nearshore and estuarine surveys indicate that the most common fishes are the herrings (alewife and Atlantic herring), the flounders (winter flounder, American plaice, witch flounder, windowpane, and smooth flounder), the codfish (Atlantic cod, haddock, Atlantic tomcod, silver hake, red hake, white hake, American pollock, and ocean pout), the sculpins (longhorn sculpin, shorthorn sculpin, and sea raven), the skates (little skate, winter skate, and thorny skate), rainbow smelt, wrymouth, rock gunnel, redfish, and the American eel.

The distribution of fish species across the five aquatic systems in coastal Maine, their relative abundance, seasonality, and regional distribution are described in table 11-2. In the NWI classification, which was used in compiling the information, systems are not always mapped according to their degree of salinity and so a problem arises when the system is applied to fish distribution. The estuarine system as described and mapped by NWI includes much habitat "historically" classified as marine. Hence, many marine fishes are found in habitats classified as estuarine. Of the 116 species recorded, 13 are strictly marine inhabitants, and 3 are found only in riverine systems. There are no strictly estuarine, lacustrine, or palustrine fish species in coastal Maine. The remaining 100 species, or 86%, inhabit two or more systems. The alewife, American eel, three-spine stickleback, brook trout, and white perch are found in all systems.

The diversity of fishes in the major systems is illustrated in figure 11-1. The marine system supports the highest diversity of fishes, followed by the estuarine system, the riverine system, the lacustrine system, and the palustrine system. Data on the relative biomass or density of fishes by aquatic systems are not available. Because of their relative mobility and general opportunistic nature, most fishes will frequent many subsystems and classes among the different habitat systems for food, shelter, or spawning. For example, most of the fishes that inhabit or pass through an estuary will frequent an intertidal emergent wetland (salt marsh) at one time or another. It is still difficult to identify which fishes are closely enough associated with a particular habitat class so that their productivity might be altered by a perturbation of that class.

In general, most fishes exhibit habitat, system, and class preferences, especially in their feeding and reproductive behavior (see sections on "Food and Feeding" and "Reproduction," this chapter). Most pelagic marine fishes (i.e., the herrings, striped bass, spiny dogfish, and mackerel) range throughout the open waters. Many typically demersal marine fishes are more closely associated with specific bottom and shore habitats. It is common to find the American eel, sea raven, sea snail, snakeblenny, rock gunnel, tautog, and radiated shanny along rocky shores and rock bottoms. Marine and estuarine aquatic beds are preferred by some sculpins, and by the red and white hake, cunner, and northern pipefish. Unconsolidated bottoms and flats in both marine and estuarine systems support chiefly sand lance, alligatorfish, wrymouth, lumpfish, cod, the flounders, and skates.

Table 11-2. The Fishes of Coastal Maine: Their Seasonality, Relative Abundance, Habitat and System Preferences, and Distribution[a]

Species	Habitat[b]	Abundance[c]	Seasonality[d]	NWI systems[e]	Nearshore and coastal distribution (regions)							Inshore rivers and lakes distribution (regions)					
					2,3[f]	2,3[g]	2[h]	2[i]	4[j]	6[k]	6[l]	1	2	3	4	5	6
Bluefin tuna	P	C	SM	M							X						
Cusk	D	C	R	M							X						
Fourbeard rockling	D	C	R	M	X				X	X	X						
Conger eel (larval)	D	UC	R	M			X	X			X						
Witch flounder	D	C	R	M	X	X			X	X	X						
Haddock	D	C	R	M	X					X	X						
Spotted hake	D	UC	SM	M					X								
Tautog	D	UC	SM	M							X						
Barndoor skate	D	C	R	M	X	X				X	X						
Atlantic hagfish	D	C	R	M	X					X	X						
Artic hookear sculpin	D	UC	R	M						X	X						
Smooth skate	D	UC	R	M						X							
Atlantic halibut	D	UC	R	M						X	X						

* Anadromous ** Catadromous @ Anadromous but does not spawn in Maine ES Endangered Species
SC Species of special concern I Introduced

[a]Bigelow and Schroeder (1953); Maine Yankee Atomic Power Co. Surveys (1970 to 1976); Chenoweth (unpublished); Central Maine Power (1974 to 1975); TRIGOM (1974); Tyler (1971); Clayton et al. (1976); Scott and Messieh (1976); Scarola (1973); Everhart (1958); Mackay et al. (1978); MDIFW (MIDAS Files).
[b]Habitat key: P=pelagic; D=demersal; SD=semidemersal.
[c]Abundance key: C=common; UC=uncommon; R=rare.
[d]Seasonality key: R=resident; SM=summer migrant.
[e]M=marine; E=estuarine; R=riverine; L=lacustrine; P=palustrine.
[f]Boothbay region
[g]Sheepscot River
[h]Montsweag Bay
[i]Sheepscot River
[j]Penobscot Bay
[k]Passamaquoddy Bay
[l]Deer Isle/Campobello

(Continued)

Table 11-2. (Continued)

Species	Habitat[b]	Abundance[c]	Seasonality[d]	NWI systems[e]	Nearshore and coastal distribution (regions) 2,3[f]	2,3[g]	2[h]	2[i]	4[j]	6[k]	6[l]	Inshore rivers and lakes distribution (regions) 1	2	3	4	5	6
Atlantic cod	D	C	R	M E	X	X	X	X	X	X	X						
Wrymouth	D	C	R	M E			X	X	X	X	X						
Alligator fish	D	C	R	M E	X			X	X	X	X						
Striped anchovy	D	UC	SM	M E			X										
American plaice	D	C	R	M E	X	X	X	X	X	X	X						
Yellowtail flounder	D	C	R	M E	X			X	X	X							
Snakeblenny	D	C	R	M E	X			X	X	X	X						
Dauhed shanny	D	UC	R	M E				X		X							
Radiated shanny	D	C	R	M E	X		X			X	X						
Ocean pout	D	C	R	M E	X		X	X	X	X	X						
Silver hake	SD	C	SM	M E	X	X	X	X	X	X	X						
Red hake	D	C	SM	M E	X	X	X	X	X								
White hake	D	C	SM	M E	X	X	X	X	X	X							
American pollock	D	C	R	M E	X		X	X	X	X	X						
Striped searobin	D	UC	R	M E			X				X						
Northern searobin	D	UC	R	M E			X				X						
Windowpane	D	C	R	M E	X		X	X	X		X						
Spiny dogfish	P	C	SM	M E	X			X	X		X						
Scup	D	UC	SM	M E			X		X		X						
Mailed sculpin	D	C	SM	M E	X		X	X	X		X						
Moustache sculpin	D	UC	R	M E				X		X							
Shorthorn sculpin	D	C	R	M E	X	X	X	X	X	X	X						
Longhorn sculpin	D	C	R	M E	X	X	X	X	X	X	X						
Capelin	P	UC	R	M E			X			X	X						
Thorny skate	D	C	R	M E				X	X	X	X						
Little skate	D	C	R	M E	X	X	X	X	X	X	X						
Winter skate	D	C	R	M E			X	X	X	X	X						
Butterfish	D	UC	SM	M E			X	X	X	X	X						
Goosefish	D	C	R	M E	X			X		X	X						

(Continued)

Table 11-2. (Continued)

Species	Habitat[b]	Abundance[c]	Seasonality[d]	NWI systems[e]	Nearshore and coastal distribution (regions)							Inshore rivers and lakes distribution (regions)					
					2,3[f]	2,3[g]	2[h]	2[i]	4[j]	6[k]	6[l]	1	2	3	4	5	6
Atlantic menhaden	P	C	SM	M E	X		X	X	X		X						
Atlantic herring	P	C	R	M E	X	X	X	X	X	X	X						
Fourspot flounder	D	UC	R	M E			X				X						
Smooth flounder	D	C	R	M E	X		X	X	X	X	X						
Winter flounder	D	C	R	M E	X	X	X	X	X	X	X						
Summer flounder	D	UC	R	M E			X				X						
Lumpfish	D	C	R	M E	X		X		X	X	X						
Sea raven	D	C	R	M E	X	X	X	X	X	X	X						
Sea snail	D	C	R	M E			X				X						
Grubby	D	C	R	M E			X	X	X								
Rock gunnel	D	C	R	M E	X		X		X	X	X						
Bluefish	P	C	SM	M E			X	X	X								
Crevalle jack	P	UC	SM	M E			X										
Atlantic mackerel	P	C	SM	M E			X	X	X		X						
Redfish	D	C	R	M E	X	X		X		X	X						
Northern pipefish	D	C	R	M E	X		X	X	X		X						
Cunner	D	C	R	M E	X	X	X	X	X		X						
American sand lance	P	C	R	M E					X		X						
Shortnose sturgeon ES*	D	R	R	M E R P			X	X									
Atlantic sturgeon SC*	D	R	R	M E R P			X				X	X	X				
Striped bass @	P	C	SM	M E R			X	X	X		X		X	X	X	X	
Blueback herring *	P	C	SM	M E R	X		X	X	X				X			X	
American shad *	P	R	SM	M E R			X	X			X	X	X		X	X	X
Hickory shad @	P	UC	SM	M E R			X										
Atlantic silversides	P	C	R	M E R			X	X	X		X						
Atlantic tomcod	D	C	R	M E R	X		X	X	X	X	X						
Blackspotted stickleback	SD	C	R	M E R			X		X		X						
Sea lamprey *	D	C	R	M E R			X				X		X			X	X
Rainbow smelt *	SD	R	R	M E R L	X		X	X	X	X	X	X	X	X	X	X	X
Atlantic salmon *	P	R	R	M E R L			X				X	X	X		X	X	X

(Continued)

Table 11-2. (Continued)

Species	Habitat[b]	Abundance[c]	Seasonality[d]	NWI systems[e]					Nearshore and coastal distribution (regions)							Inshore rivers and lakes distribution (regions)					
									2,3[f]	2,3[g]	2[h]	2[i]	4[j]	6[k]	6[l]	1	2	3	4	5	6
Coho salmon I*	P	C	R	M	E	R	L				X										
Nine-spine stickleback	SD	C	R	M	E	R	L				X		X		X		X	X	X	X	X
Four-spine stickleback	SD	C	R	M	E	R	L				X		X		X				X		
Alewife *	P	C	R	M	E	R	L	P	X		X	X	X	X	X	X	X	X	X	X	X
American eel **	D	C	R	M	E	R	L	P	X	X	X		X		X	X	X	X	X	X	X
White perch	SD	C	R	M	E	R	L	P			X	X			X	X	X	X	X	X	X
Three-spine stickleback	SD	C	R	M	E	R	L	P	X		X		X		X		X		X	X	X
Brook trout	P	C	R	M	E	R	L	P					X		X	X	X	X	X	X	X
Mummichog	SD	C	D		E	R	L				X		X		X		X				
Brown trout I	P	C	R		E	R	L									X	X	X	X	X	X
Banded killifish	SD	C	R		E	R	L									X	X	X	X	X	X
Carp I	D	C	R			R	L									X	X				
Blacknose dace	SD	C	R			R										X	X	X	X		
Longnose dace	SD	C	R			R											X				
Creek chub	SD	C	R			R										X			X	X	X
Chain pickerel	SD	C	R			R	L	P								X	X	X	X	X	X
Brindle shiner	SD	UC	R			R	L	P													
Redbreast sunfish	SD	C	R			R	L	P									X				X
Pumpkinseed sunfish	SD	C	R			R	L	P								X	X	X	X	X	X
Brook stickleback	SD	UC	R			R	L	P									X				
Largemouth bass I	SD	C	R			R	L	P								X	X	X	X		X
Smallmouth bass I	SD	C	R			R	L	P								X	X	X	X	X	X
Goldenshiner	SD	C	R			R	L	P								X	X	X	X	X	X
Blacknose shiner	SD	C	R			R	L	P									X				
Yellow perch	SD	C	R			R	L	P								X	X	X	X	X	X
Finescale dace	SD	C	R			R	L	P									X				X
Fathead minnow	SD	C	R			R	L	P									X				

(Continued)

Table 11-2. (Concluded)

Species	Habitat[b]	Abundance[c]	Seasonality[d]	NWI systems[e]	Nearshore and coastal distribution (regions)							Inshore rivers and lakes distribution (regions)					
					2,3[f]	2,3[g]	2[h]	2[i]	4[j]	6[k]	6[l]	1	2	3	4	5	6
Pearl dace	SD	C	R	R L P								X	X				
Northern redbelly dace	SD	C	R	R L P								X		X	X		X
Blackchin shiner	SD	C	R	R L										X			
Longnose sucker	D	C	R	R L									X				
White sucker	D	C	R	R L								X	X	X	X	X	X
Lake whitefish	SD	C	R	R L									X				
Lake trout	SD	C	R	R L									X	X	X	X	X
Slimy sculpin	SD	C	R	R L									X				
Lake chub	SD	C	R	R L									X	X			
Brown bullhead	D	C	R	R L								X	X	X	X	X	X
Burbat	D	C	R	R L									X				
Common shiner	SD	C	R	R L								X	X	X			
Rainbow trout I	SD	C	R	R L								X	X		X	X	
Fallfish	SD	C	R	R L								X	X		X		X
Landlocked salmon	SD	C	R	R L								X	X	X	X	X	X
Round whitefish	SD	UC	R	R L									X				
Sunapee trout	SD	C		R L												X	

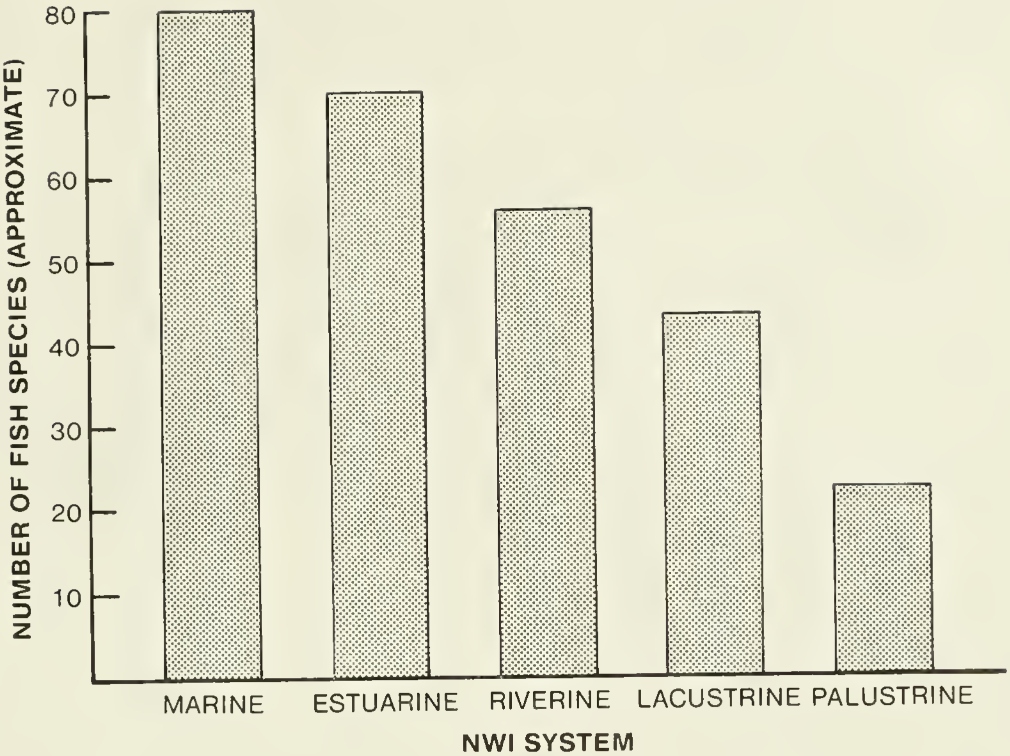

Figure 11-1. Diversity of fishes in Maine systems.

The major fishes of the rivers, lakes, and ponds are trout, sunfish, bass, sticklebacks, whitefish, catfish, shiners, dace, chubs, suckers, and perch. The freshwater fishes are important primarily for sport fishing. The trouts and bass are the most sought after species. The ecological role and/or contribution of some of the less conspicuous species (dace, chubs, shiners, and sticklebacks) generally is known. The freshwater systems (lacustrine, riverine, and palustrine) support a lower diversity of fishes than the marine and estuarine systems combined. The species composition of freshwater fish reflects a mix of both warmwater and coldwater fishes, although the abundance of coldwater species (e.g., trout and salmon) generally increases from southwest to northeast (see chapter 7, "The Lacustrine System"). A number of freshwater species are widely distributed among the characterization area's lakes and streams (table 11-2). Many are limited in their distribution by water quality and/or barriers. Historically, the Kennebec River (region 2) hosted the highest diversity of freshwater and anadromous fishes in the state of Maine (Foye et al. 1969). Excessive use of dams and pollution of the water by municipal and industrial wastes were responsible for the collapse of the Kennebec River fisheries.

Many freshwater fishes have system and class preferences. Trout, salmon, burbot, and whitefish prefer deep, cool lakes and swift streams. Largemouth bass, chain pickerel, and sunfish are found along the quiet vegetated shores of most lakes and ponds. The brown bullhead prefers fairly deep, weedy lake bottoms and slow fresh streams. Finescale dace and northern redbelly dace principally inhabit cool, boggy waters. Good coverage of the general distribution and habitat preferences of freshwater fishes is found in Scarola (1973), Everhart (1958), and Scott and Crossman (1973).

Seasonal Occurrence and Migration

Water temperature is one of the major factors controlling the seasonal and daily movements of fish populations. Many fish species have preferred temperature ranges and move in response to seasonal and local changes in temperature. Gulf of Maine waters have a narrower annual temperature range than the neighboring mid-Atlantic Bight waters to the south. Colton (1972) discusses the effects of these temperature trends on the distribution and migration of certain marine fishes in the Gulf of Maine. The relatively stable seasonal temperatures tend to support a high proportion of resident marine fishes. The mid-Atlantic waters, on the other hand, support few permanent residents and are inhabited by continuously shifting populations of southern (temperate) migrants and some northern species.

Some southern migrants to the mid-Atlantic Bight waters follow the summer thermoclines up into the Gulf of Maine. Many of these species are present in sufficient numbers to play a significant role in the ecology of coastal Maine. Common summer migrants inshore and along the coast are spiny dogfish, scup, silver hake, spotted hake, red hake, white hake, tautog, American shad, hickory shad, striped bass, menhaden, blueback herring, bluefish, Atlantic mackerel, butterfish and bluefin tuna. Many of these species (e.g., tuna, bluefish, mackerel, and striped bass) are important sport fishes in Maine and other Atlantic states. Not all of these species reach eastern Maine and Canada. Many are uncommon east of the Penobscot Bay area (scup, spotted hake, hickory shad, tautog, butterfish, and bluefish). Most of these summer migrants leave coastal Maine with the onset of cooling autumn water temperatures and disperse to the south. There is an additional winter dispersal of cod and pollock from the Gulf of Maine to waters south of Cape Cod but their numbers do not rival the summer migrants from the mid-Atlantic (TRIGOM 1974).

Most of the resident fish species exhibit some form of seasonal and/or daily movements, either inshore to offshore or from shallow flats to deeper water, in response to changes in temperature. Many resident marine and estuarine fishes move offshore into deeper (warmer) waters to overwinter (e.g., the flounders, the skates, cunner, lumpfish, and alewife). Resident populations of brown, brook, and rainbow trout show marked movements along river reaches, in and out of the lakes through connecting streams. Of special interest are the resident anadromous and catadromous fishes.

Anadromous and Catadromous Fish Distribution

Coastal Maine supports relatively healthy and diverse populations of anadromous species in comparison with many other Atlantic coastal areas. Resident anadromous fishes include the shortnose and Atlantic sturgeon (both are rare and the shortnose is an endangered species), alewife (common throughout), rainbow smelt (common throughout), sea lamprey (common in midcoastal and eastern Maine), and Atlantic salmon (rare in Maine but its populations are recovering in the Sheepscot, Ducktrap, Machias, East Machias, Dennys, and Pleasant Rivers, and Penobscot, Kennebec, and Narraguagus drainages). The resident American eel, a catadromous fish, is perhaps the most ubiquitous fish in Maine. It is found in almost every major drainage and aquatic system (see atlas map 4).

Two of the summer migrants, American shad and blueback herring, are anadromous fishes, spending part of their life cycle in marine waters and swimming up estuaries and rivers to spawn in fresh water. Striped bass are anadromous in the southern part of their range but they do not commonly spawn in Maine.

Maine's historically rich populations of anadromous fishes declined near the turn of the century through the 1960s as a result of dams that blocked pathways to spawning areas. Altered water flow and river pollution by municipal and industrial wastes also were factors. The status of recovery, problems remaining, and management strategy for the enhancement of anadromous fish resources are discussed under "Management," in this chapter.

REPRODUCTION

Spawning habits are known for most of Maine's resident marine and estuarine fishes, notably the anadromous fishes, and sport and commercial fishes. Detailed life history information by species is available in Bigelow and Schroeder (1953), Everhart (1958), Clayton and coworkers (1976), Scarola (1973), TRIGOM (1974), and Scott and Crossman (1973).

Spawning adults and the eggs and larvae of fishes are particularly sensitive to changes in their environments. Many species require specific habitats, migratory pathways, and environmental conditions (e.g., temperature and salinity) for successful spawning. Anadromous fishes, such as salmon, alewife, smelt, and blueback herring, require unobstructed passage through estuarine and riverine systems to suitable freshwater spawning grounds; some of these fish negotiate obstructions better than others.

Many species that spawn offshore, such as the Atlantic cod and Atlantic herring, migrate to certain open water areas to spawn. Spawning activity is synchronized for many species. This usually results in greater than normal concentrations of a species in a spawning area. As a result the whole population of a species is vulnerable to a single adverse event (e.g., fishing and oil spills). The eggs and larvae of most fishes are generally vulnerable to predation and environmental changes. They are relatively concentrated in numbers and have limited or no powers of locomotion by which to leave an unfavorable area.

Fecundity

The success of reproduction is determined largely by the survival of the year classes during their early life stages. Natural mortality usually is very high during that time. The reproductive strategy of most fishes involves the external fertilization of great numbers of eggs. A small percentage survive to adulthood. Fishes that show a higher degree of parental care usually lay fewer eggs. There usually is a trade-off effect between the number of eggs laid and the rate of survival of the young to maturity; that is, the energy that goes into producing large quantities of eggs is not available to provide care for the young.

The Atlantic cod, a pelagic open-water spawner, can produce up to 9 million eggs per female per season. The females provide little or no care after the eggs are released in the vicinity of spawning males. This is true of most marine spawners. Other fish species that provide little or no care to eggs or young are the carp, chain pickerel, golden shiner, whitefish, lake trout, suckers, yellow perch, and the alewife. There are a number of fishes (e.g., sea lamprey, salmon, trout, and fallfish) which build nests for the eggs but desert them soon after spawning. In contrast, the sticklebacks, sunfish, bass, brown bullhead, slimy sculpin, and fathead minnow make elaborate nests and provide parental care to the developing young for several days or weeks. The usual number of eggs for the sticklebacks ranges from 20 to 100 (Clayton et al. 1976).

Redfish and northern pipefish provide even more protection to eggs. Their eggs are protected in the oviduct or brood pouch. The young are born in a more advanced stage of development. In general, fishes that utilize the rivers, lakes, and estuaries for spawning are generally less fecund than marine spawners and give a higher degree of parental care.

Spawning Habits

Reproductive habits of the fishes of coastal Maine are summarized in table 11-3. The spawning season for marine fishes is well distributed throughout the year with notable peaks in mid-winter (primarily resident fish) and summer (primarily summer migrants).

Of the 16 summer migrant species, 4 are known to spawn in coastal Maine or its waters offshore (silver, red, and white hake, and blueback herring), 2 are noted as historically common anadromous fishes (American shad and striped bass) and the others do not spawn in coastal Maine.

Spawning activities generally commence earlier in western than in eastern Maine (Bigelow and Schroeder 1953). Among estuarine and freshwater fishes, spawning activity is heaviest from May through July. Exceptions are salmon, whitefish, and trout, which spawn in late fall (October and November, principally). Data on preferred water temperature for spawning in Maine are lacking for many freshwater and marine species, including some very common marine fishes (e.g., sculpins, skates, hakes, sticklebacks, sea snails, sand lance, eel, sea raven, smooth flounder, and rock gunnel).

Eggs spawned externally by fishes are either planktonic (pelagic) or demersal (table 11-3). Planktonic eggs are buoyant, have a specific gravity about equal to that of fresh water, and usually float freely in the water column. Most marine fishes, such as the Atlantic cod, silver hake, yellowtail flounder, and American plaice produce planktonic eggs. Egg survival is sometimes affected by currents, oil slicks, and other surface disturbances. Most estuarine and freshwater spawners lay demersal eggs, which are relatively heavy, usually adhesive, and sink to the bottom or adhere to submerged substrates. These demersal eggs are particularly vulnerable to water level changes, local water quality conditions, and smothering by sediments or other solids. The large expanse of relatively shallow, protected waters (marine and estuarine subtidal) in coastal Maine provides suitable and abundant habitat for the spawning of many demersal egg-bearing fishes (i.e., sculpins, winter flounder, rock gunnel, tomcod, and skates).

Table 11-3. Spawning Characteristics of Fishes of Coastal Maine[a].

Species	Principal spawning months JFMAMJJASOND	Spawning habitat[b]	Egg deposition[c]	Spawning temperatures
Cusk	AMJJ	M1OW	P	-
Fourbeard rockling	AMJJ	M1OW	P	55°-66°F
Atlantic cod	JFMA D	M1OW	P	38°-47°F
Haddock	FMAM	M1OW	P	37°-41°F
American pollock	J ND	M1OW	P	38°-48°F
Goosefish	JJAS	M1OW	P	41°-64°F
Silver hake	JJASO	M1OW	P	41°-55°F
White hake	FMAMJJ	M1OW	P	-
Red hake	JJASO	M1OW	P	-
Cunner	JJA	M1OW	P	55°-65°F
American eel	J D	M1OW	P	-
Conger eel	JA	M1OW	U	-
Tautog	JJ	M1OW	P	17°-20°C
Northern pipefish	MAMJJA	M	O	-
Redfish	MJJA	M	O	37°-49°F
Wrymouth	JF D	M	U	-
Ocean pout	SO	M1RB	D	10°C
Sea snails	J D	M1,E1RB	D	-
American sand lance	JFMA D	M1UB	D	-
Witch flounder	AMJJA	M1UB	P	45°-55°F
American plaice	FMAM	M1UB	P	37°-40°F
Yellowtail flounder	MAMJJA	M1UB	P	50°-52°F
Snakeblenny	JF D	M1UB	U	-
Windowpane	MJJA	M1UB	P	50°-60°F

[a]Bigelow and Schroeder (1953); Clayton et al. (1976); MDIFW (1976); Colton (1979); Everhart (1958); Scarola (1973).

[b]Habitat Key: M=Marine, E=Estuarine. 1=subtidal, 2=intertidal; P=Palustrine; R=Riverine, 1=tidal, 2=lower perennial, 3=upper perennial; L=Lacustrine, 1=littoral, 2=limnetic; OW=open water, UB=unconsolidated bottom, RB=rock bottom, AB=aquatic bed, EM=emergent, RS=rocky shore.

[c]Egg Deposition Key: P=Planktonic, D=Demersal, O=Ovoviviparous, U=Unknown SD=Semi-demersal.

(continued)

Table 11-3. (Continued)

Species	Principal spawning month JFMAMJJASOND	Spawning habitat	Egg deposition	Spawning temperature
Mailed sculpin	J	M1UB	D	-
Thorny skate	AMJJAS	M1UB	U	-
Moustache sculpin	JF D	M1UB	U	-
Atlantic herring	SON	M1UB	D	3°-11° C
Lumpfish	FMAM	M1UB	D	-
Sea raven	OND	M1UB	D	-
Rock gunnel	JFM ND	M1UB	D	-
Little skate	JFMAMJJASOND	M1UB	D	-
Winter skate	JASON	M1UB	U	-
Longhorn sculpin	JF ND	M1UB	D	-
Smooth flounder	JFM D	M1, E1UB	U	-
Alligatorfish	OND	M1UB	U	-
Grubby	JFMAMJ D	M1, E1, UB, AB	D	-
Shorthorn sculpin	JF ND	M1UB, AB	D	-
Radiated shanny	MJJA	M	U	-
Atlantic tomcod	JF ND	E	D	40°-44° F
Mummichog	JJA	E	D	-
Threespine stickleback	MJ	E2EM, RS, UB	D	-
Fourspine stickleback	JJ	E2EM	D	70° F
Ninespine stickleback	MJJ	E2EM	D	-
Blackspotted stickleback	MJ	E2EM	D	-
Atlantic silversides	MJJA	E2EM; M1, E1UB	D	68° F
Winter flounder	MAMJ	E1UB	D	31°-37° F
White perch	AMJ	E; L; P; R	D	52°-60° F
Banded killifish	JA	RAB, L, PAB	D	-
Carp	AMJ	R, PAB	D	-
Shortnose sturgeon	AMJ	R, P	U	15°-18° C
Atlantic sturgeon	MJJ	R2	D	-
Blueback herring	MJJ	R1	D	70°-75° F
Rainbow smelt	AM	R1, 2	D	50°-57° F
American shad	MJ	R2, 3	D	50°-63° F
Sea lamprey	MJJA	R3UB	D	50°-68° F
Atlantic salmon	ON	R3UB	D	4° C
Alewife	AMJ	P; R2; L	D	55°-60° F
Brook trout	ON	R3UB; P	D	40° F
Brown trout	ON	R3UB	D	-
Blacknose dace	AMJ	R3UB	D	-
Creek chub	AM	R3UB	D	-
Golden shiner	MJJ	RAB	D	-
Yellow perch	AM	R, L, PAB	SD	44°-54° F
Finescale dace	JJA	R, PAB	D	-

(continued)

Table 11-3. (Concluded)

Species	Principal spawning months JFMAMJJASOND	Spawning habitat	Egg deposition	Spawning temperature
Pearl dace	AM	R3UB	D	-
Longnose sucker	M	R,PUB	D	-
White sucker	M	R,PUB	D	-
Lake whitefish	ND	R2,3;L2RB	D	$40^{\circ}-50^{\circ}F$
Brown bullhead	MJJ	RUB	D	$>65^{\circ}F$
Smallmouth bass	JJ	R,L,PUB	D	$59^{\circ}-69^{\circ}F$
Common shiner	AMJ	R3UB	D	$60^{\circ}-65^{\circ}F$
Longnose dace	AMJJ	R3UB	D	-
Rainbow trout	AM	R2,3UB	D	$50^{\circ}F$
Fallfish	MJ	R,LUB	D	-
Landlocked Atlantic salmon	SON	R,L	D	-
Blacknose shiner	AMJ	R	U	-
Bridle shiner	MJJ	RAB,UB	D	$58^{\circ}-80^{\circ}F$
Slimy sculpin	AMJ	R,LUB	D	-
Northern redbelly dace	JJA	R,PAB	D	-
Brook stickleback	MJ	R	D	-
Largemouth bass	J	L,P AB,UB	D	$60^{\circ}-70^{\circ}F$
Fathead minnow	AMJ	LUB	D	-
Lake chub	JA	R	D	-
Burbot	JFM D	RUB,LUB	D	-
Lake trout	SON	L2UB	D	$37^{\circ}F$
Round whitefish	ND	R2,3,LUB	D	$40^{\circ}F$
Redbreast sunfish	J	L,PUB	D	$65^{\circ}-70^{\circ}F$
Pumpkinseed sunfish	JA	L,PUB	D	-
Chain pickerel	AM	P,L	D	-
Sunapee trout	SON	L2UB	D	-

EARLY LIFE HISTORY

Larval fish, often called fry, are particularly vulnerable to predation and environmental stress. The larvae of most fishes are planktonic for some time, have limited powers of locomotion and drift freely in the water column. The period of larval life varies for different species and may last from a few days to several years. The larvae of the winter flounder are planktonic for about 50 days. Atlantic herring remain in the larval stage for 5 to 7 months (Graham et al. 1972). Sea lamprey larvae require 5 or more years before undergoing metamorphosis (Lagler et al. 1962). The average duration of larval stages in the Gulf of Maine is about 3 to 5 months. Water temperature also influences the duration of the larval stage; that is, the higher the temperature, the faster the development of the eggs and larvae.

The larval stage in fishes is terminated at metamorphosis, when the fishes develop adult features and habits. At this point they are considered juveniles. Final development and maturation of the gonads signals the onset of sexual maturity. The time required to attain sexual maturity varies among species and with water temperatures. For example, Atlantic silverside and sticklebacks reach maturity within one year after hatching, whereas freshwater eels require 6 to 12 years. The Atlantic sturgeon may take 15 or more years (Lagler et al. 1962).

Larval Populations

Planktonic eggs and larvae are seasonally important components of the plankton communities (TRIGOM 1974). Detailed data are available for the midcoast region (lower Sheepscot-Damariscotta estuaries), offshore Gulf of Maine, and the Bay of Fundy. The species compositon and seasonal abundance of the estuarine larval populations have been described for the Sheepscot/Back River estuaries by Maine Yankee Atomic Power Company surveys (1970 to 1976), for the lower Sheepscot estuary by Chenoweth (1973), and for the mid-coast region by Graham and Boyar (1965) and Graham and coworkers (1972). The offshore marine larvae in the Gulf of Maine and Georges Bank were sampled by Marak and Colton (1961) and Marak and coworkers (1962a and 1962b). Fish and Johnson (1937) surveyed the marine larvae in the Bay of Fundy and northern Gulf of Maine waters. Some of these data are given in table 11-4. Complete lists of all larval species found in the marine and estuarine surveys are given in appendix tables 8 and 9.

Fish larvae in the offshore waters are dominated by the larvae of resident fishes (cod, haddock, sand lance, and flounder). Silver hake larvae dominate the larvae of summer migrant fishes. Larval populations in the Bay of Fundy are dominated by the larvae of Atlantic herring and redfish, which are typical northern resident species. In the Sheepscot estuary, larval abundance is greatest from late winter through spring, with greatest concentrations in the upper estuaries (figure 11-2). These estuarine larvae are composed of both marine and estuarine fishes. Species that utilize the estuaries as primary spawning and/or nursery areas (as indicated by the abundance of larvae) include the wrymouth, rock gunnel, sculpins, sea snails and snakeblenny (Chenoweth 1973), Atlantic herring, winter flounder, and Atlantic tomcod (Maine Yankee Atomic Power Co. 1976).

Table 11-4. The Relative Abundance (expressed as percentage composition) of Larval Fishes Inhabiting the Marine Offshore Gulf of Maine, Lower Sheepscot Estuary and Upper Sheepscot Estuary (Montsweag Bay)[a]

Location and Years of Sampling							
Marine				Estuarine			
Northern Gulf of Maine/ Bay of Fundy (1937)		Gulf of Maine/Georges Bank (1961 to 1962)		Lower Sheepscot (1973)		Montsweag Bay (1970 to 1976)	
Atlantic herring	48	Haddock	31	Sculpins	45	Rock gunnel	31
Redfish	48	Yellowtail flounder	9	Rock gunnel	35	Atlantic herring	21
Haddock	2	Atlantic cod	9	Sea snails	8	Rainbow smelt	19
Rock gunnel	1	American sand lance	7	Atlantic herring	6	Sculpins	16
Witch flounder	1	Silver hake	6	Snakeblenny	2	Flounders	6
		American plaice	5	Wrymouth	1	American eel	2
		Fourbeard rockling	5			Sea snails	1
		Atlantic herring	4			Atlantic tomcod	1
		Red hake	3				
		Cunner	3				
		Cusk	2				
		American pollock	2				
		Scup	2				
		White hake	1				
		Witch flounder	1				

[a]TRIGOM 1974

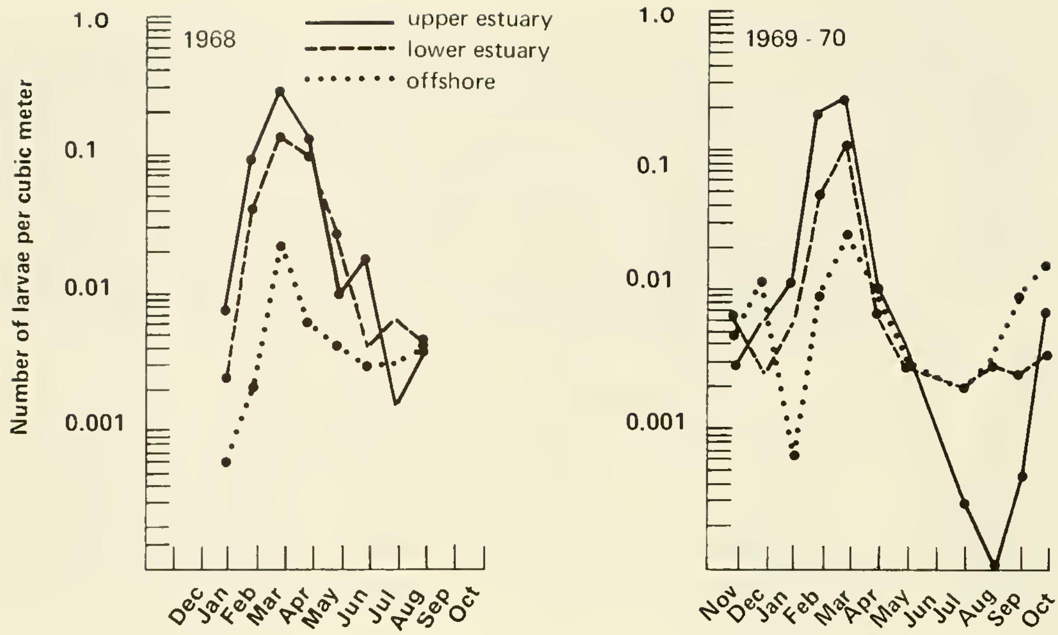

Figure 11-2. Seasonal abundance of fish larvae in the upper estuarine, lower estuarine, and offshore areas of the Boothbay region (Chenoweth 1973).

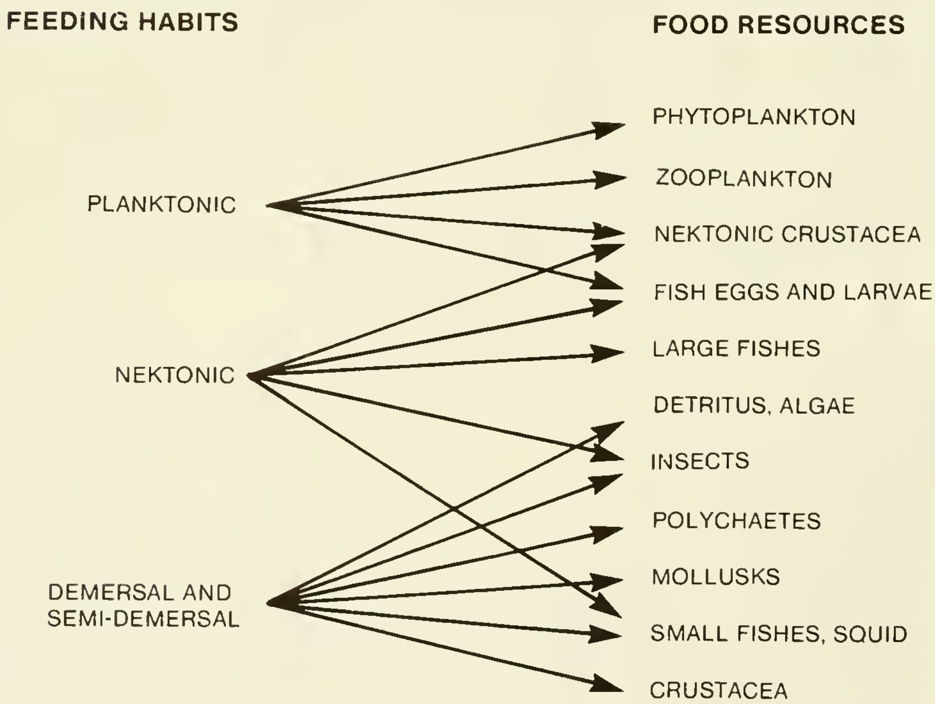

Figure 11-3. Feeding habits and food resources of fishes.

FOOD AND FEEDING HABITS

In the context of the total ecosystem, fish species may best be considered as a group occupying a specific feeding niche (Langton and Bowman 1978). These niches are determined by the fishes' feeding habits (food items and habitats used) and may change with size or life stage. The majority of fishes are secondary or higher level consumers in their respective aquatic systems. A single species may utilize several different feeding habits during its various life stages. Different species may share the same food resources in a given area or at a given time. This information is necessary to develop an accurate understanding of energy transfer and trophic organization in aquatic systems.

Fishes are classified as planktonic, nektonic, or demersal/semidemersal feeders (figure 11-3). Planktonic feeders, such as the herrings, Atlantic menhaden, and American sand lance feed high in the water column. Planktonic food organisms for these fish are largely pelagic crustaceans (amphipods, copepods, euphausiids, and mysids), schooling fishes, fish eggs, and larvae. Fishes that feed on the nekton feed throughout the water column, on pelagic crustaceans and fishes. The majority of the characterization area's migratory fishes are nektonic feeders. The demersal/semidemersal feeders utilize typical bottom food items, such as crustaceans, molluscs, echinoderms, fish, polychaete worms, insects, algae, and detritus. The majority of the area's resident marine, estuarine and freshwater fishes are demersal/semidemersal feeders. The feeding habits and major food items of the fishes of coastal Maine are listed in table 11-5. Data are organized by habitat, feeding habit and principal foods. Fishes that share a given resource and may be impacted by the availability or quality of food items may be perceived as a group.

Detailed published work on food habits of Maine marine and estuarine fishes are Tyler (1971 and 1972), Langton and Bowman (1978), and Maurer and Bowman (1977). The latter two sources are the products of a comprehensive ongoing effort by the National Marine Fisheries Service to compile food habit data on 80 major species of Northwest Atlantic marine fishes.

Tyler (1972) looked at the food resources of the demersal marine fish of Passamaquoddy Bay and compared the diets of the residents and seasonal migrants for overlap and seasonal specialization. He found that the seasonal migrants did not feed on a unique set of prey species but shared some food resources with the resident species. Among the factors determining which species a predator took were prey size, prey habitat (whether the prey were nektonic, epifaunal, or infaunal), and whether or not the prey had a hard shell (Tyler 1972). Within the species, diet varied with the size of the individual.

Langton and Bowman's (1978) investigations also indicate that when the diets of taxonomically related pairs of species are analyzed, important differences are apparent (figure 11-4). The similarity in diet is a relative measure of overlap in food habits, i.e., use of the same resource by more than one predator regardless of food abundance. Competition for food exists only if the demand for prey exceeds the immediate supply. The index of diet overlap shows where there is a potential for food resource competition given a certain set of circumstances, e.g., significant decreases in prey populations and/or increases in predator populations, or reduced feeding areas.

Table 11-5. Feeding Habits and Major Food Items of the Fishes of Coastal Maine[a]

	Marine, Estuarine, and Anadromous Fishes			
	Specues	Food Items		Species	Food Items
Planktonic					
	American sand lance	C CH		Atlantic herring	C Ch
A,SM	Blueback herring	C FE	A,SM	(American shad)	C FE
A	Alewife	C	SM	Atlantic menhaden	D C
Nektonic					
	American pollock	C F		Alligatorfish	C
	Sea snails	C	SM	Atlantic mackerel	C M F
	Redfish	C		Northern pipefish	C F M
SM	Red hake	C F		White perch	C S F I
SM	Spiny dogfish	F S	SM	Bluefish	F S
SM	White hake	F C	SM	Striped bass	E
SM	Bluefin tuna	F	A	Rainbow smelt	F C I
A	Atlantic salmon	F I		Brook trout	F I
	Brown trout	F I	A	Sea lamprey	Pa Dt
SM	Silver hake	F C			

Key:

A Anadromous	F Fishes	T Tunicates	P Polychaetes
C Catadromous	C Crustaceans	Ch Chaetognaths	Co Coelenterates
SM Summer migrant	D Diatoms	M Molluscs	Pa Parasite
WM Winter migrant	A Animal remains	F Echinoderms	I Insects
() Uncommon	FE Fish eggs and larvac	S Squid	Dt Detritus
			IL Insect larvae

[a]Bigelow and Schroeder (1953); Clayton et al. (1976); Everhart (1958); Langton and Bowman (1978); and Scarola (1973).

(Continued)

Table 11-5. (Continued)

	Marine, Estuarine, and Anadromous Fishes										
	Species	Food Items					Species	Food Items			
Necktonic/demersal											
	Cunner	C	M	F			Atlantic cod	F	C	M	
Demersal/semidemersal											
	Blackspotted stickleback	D	F				Nine-spine stickleback	D	F	C	
	Four-spine stickleback	D	F				Three-spine stickleback	D	F	P	
C	American eel	C	F	M	P		Fourbeard rockling	C	A		
	Snakeblenny	C	M				Windowpane	C	E		
	Mailed sculpin	C	P				Lumpfish	C	P	M	F
	Smooth flounder	C	P				Atlantic silversides	C	M	P	D
	Grubby	C	P	M	P		Shorthorn sculpin	C	P		
	Atlantic tomcod	C	P	M	F		Little skate	C	P	M	
	Longhorn sculpin	C	F	P			Banded killifish	Dt	C	I	
	Mummichog	Dt	C				American plaice	E	C	M	
	Ocean pout	E	M	C			Haddock	E	C	P	F
	Cusk	F	C	M			Thorny skate	F	P	C	
	(Barndoor skate)	F	C				Goosefish	F	S		
	(Atlantic hagfish)	F	C				(Atlantic halibut)	F	C		
	Sea raven	F	M			SM	Tautog	M	C		
	Rock gunnel	M	C	P			Wrymouth	P	C		
	Witch flounder	P	E				Yellowtail flounder	P	C		
SM	Scup	P	Co	C	M		Winter skate	P	C		
	Winter flounder	P	Co			A	Atlantic sturgeon	P	C	M	Dt
A	Shortnose sturgeon	P	C			SM	Butterfish	T	C		

(Continued)

Table 11-5. (Concluded)

Freshwater fishes												
Species	Food items					Species	Food items					
Demersal/semidemersal												
Banded killifish	Dt	C	I			Northern redbelly dace	D					
Common shiner	D	C	I			Golden shiner	D	Dt	I	IL	M	F
Blacknose dace	I	D				Finescale dace	I	D				
Fathead minnow	I					Pearl dace	I					
Blackchin skiner	I					Slimy sculpin	I	C	F	D		
Lake chub	I	C	F	D		Yellow perch	I	C	F			
Largemouth bass	I	C	F	P	M	Smallmouth bass	I	C	F			
Carp	I	Dt	M	P		Creek chub	I	C	M	F	Dt	
Redbreast sunfish	I	M	F			Pumpkinseed sunfish	I	M	C	F		
Rainbow trout	I	F				Fallfish	I	F	C	D		
Bridle shiner	C	I	D			Blacknose shiner	C	I	D			
Longnose sucker	IL	M	C	P	D	White sucker	IL	M	P	D		
Lake whitefish	IL	M	C	F		Round whitefish	IL	M				
Brown bullhead	IL	C	M	F	D	Longnose dace	IL					
Chain pickerel	F					Lake trout	F	C				
Burbot	F					Brook trout	F	I				
Brown trout	F	I				Coho salmon	F	I				
Sunapee trout	F	I										

PREDATORS	Atlantic cod	Pollock	Silver hake	White hake	Cusk	Red hake	Haddock	Longfin hake	Fourbeard rockling	Ocean pout
Atlantic cod										
Pollock	69									
Silver hake	59	69								
White hake	61	57	56							
Cusk	27	30	16	23						
Red hake	41	47	70	48	38					
Haddock	18	15	14	14	19	23				
Longfin hake	2	5	2	1	13	7	6			
Fourbeard rockling	18	20	8	6	42	14	25	4		
Ocean pout	6	3	3	4	6	11	31	28	4	

0 <30 | 30 <60 | 60 <100

Figure 11-4. The percentage similarity between the diets of ten species of gadiform fishes in the Gulf of Maine (numerical values given in the left half of the matrix, ranges in the right half), Langton and Bowman (1978).

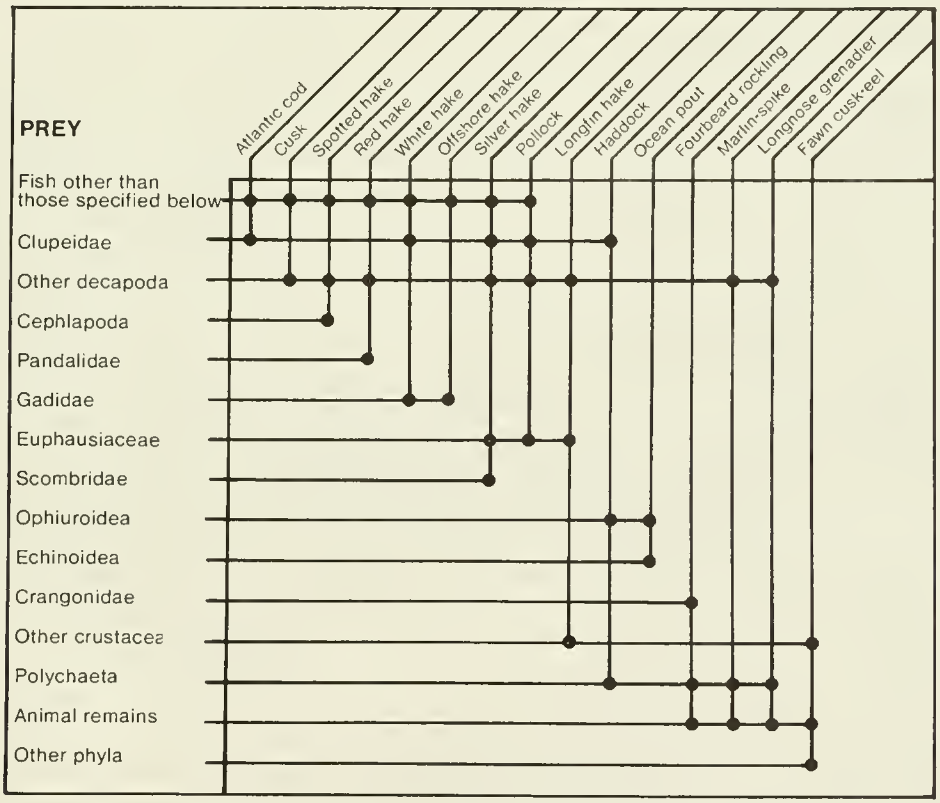

Figure 11-5. A food partition plot indicating the major prey of each of 15 predacious fishes of the Gulf of Maine. Major prey is defined as any prey category comprising ≥10% by weight of the diet for any one predator (Langton and Bowman 1978).

Community interactions are shown by means of a partition plot (figure 11-5). From this diagram it is clear that the Northwest Atlantic gadids show a reasonable degree of food partitioning, since major prey, except for broadest categories (e.g., other fishes and other Decapoda) is rarely shared by more than two or three predators. A similar situation has been described for a number of freshwater and other marine fish communities. Langton and Bowman (1978) support the contention that the cod fish evolved in a system where the availability of food was the controlling factor. In other words, competition for food, as the limiting resource, resulted in the development of different food habits by each species of fish.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE

Environmental factors, both natural and human-originated, influence the abundance, distribution, and behavior of fish populations. These factors include water temperature, salinity, food availability, competition, predation, rate of harvest, disease and parasites, water quality, and dams and other obstructions. Their effects on fish may be direct (e.g., causing deaths) or indirect (e.g., decreasing food supplies). Early life stages, egg and larvae, are most vulnerable to stress from the environment, since they are less mobile, and usually occur close to shore where human activity is more concentrated (Clayton et al. 1976).

Water Temperature

Temperature is a major factor affecting the distribution of most fish populations. Seasonal and daily movements, gonad development, spawning activities, growth rates, osmoregulation, respiration, and the duration and success of egg and larval development vary with temperature. In general, marine fishes have a narrower range of temperature tolerance than estuarine fishes. This reflects the relative stability of the marine environment as compared to the fluctuating conditions of estuaries. Most estuarine and anadromous fishes are adapted to the warmer water temperatures typical of shallow estuarine or riverine environments in summer (16 to 26°C; 61 to 79°F). Pelagic fishes are generally more sensitive to temperature changes than demersal fishes.

Targett and McCleave (1974) looked at the distribution and abundance of fishes in Bailey Cove (Sheepscot estuary, region 2) during the summer in relation to water temperature. Mummichogs, smooth flounders, Atlantic silversides, and Atlantic herring were the dominant fishes captured (98% of the catch). The mummichogs and Atlantic silversides were caught primarily in the inner cove (warmer, shallower water). Atlantic herring, smooth flounder, winter flounder, alewives, and Atlantic tomcod were captured near the outer margin (deeper, cooler, water) of the cove; American eel and blueback herring were found to use the cove primarily at night, when waters were cooler (McCleave and Fried 1975). The latter two groups of fishes tend to avoid the tidal cove when the waters become too warm.

Other examples of temperature preference were shown in a study of the seasonal abundance of pelagic fishes in the deeper, main channels of the Sheepscot River estuary. Rainbow smelt were found to be the only year-round resident in the upper estuary (Recksiek and McCleave 1973). The relatively warm Back River estuary supports abundant populations of alewives, blueback herring, and

Atlantic menhaden in the summer months; whereas Atlantic mackerel, Atlantic herring and spiny dogfish are most abundant in the more marine (and therefore cooler) Sheepscot River estuary. Prolonged, near-freezing temperatures, rather than the annual temperature range, limit the habitability of temperate estuaries by pelagic fishes (Recksiek and McCleave 1973). The authors hypothesize that those pelagic species would be most affected by an altered temperature regime.

Data on temperature effects on fish, other than mortality, are scarce. Potential thermal impacts on fish populations, therefore, must be considered before activities that could alter the temperature regime of a body of water are undertaken. Human activities that have the potential to alter water temperature and, therefore, the habitat of fishes, are summarized in table 11-6. These are primarily problems in freshwater and estuarine systems. Some activities raise water temperature by increasing surface water exposure to the sun. Examples are: the removal of stream cover vegetation (common in agriculture, forestry, and construction practices), and water flow impedimentation upstream from dams and impoundments. Another heat source is the direct addition of heated effluent from municipal and industrial waste disposal and power-producing operations. Eight power plants discharge cooling water within the characterization area (see chapter 3, "Human Impacts on the Ecosystem").

Salinity

Marine waters generally are defined as those having a salinity concentration of >30 ppt. Estuarine salinities typically range from 0.5 to 30 ppt and fresh water is <0.5 ppt. Salinity is fairly constant (about 32 ppt) in the open ocean and is not considered a major factor in determining the distribution of marine fishes. In estuarine environments, however, salinity determines distribution of most organisms (Recksiek and McCleave 1973). Each species, and often each life stage, has a preference and a tolerance range. Anadromous fishes such as the Atlantic salmon, alewife, rainbow smelt, American shad, and blueback herring, spend their adult life in saline waters but return to freshwater rivers and streams to spawn. The eggs and larvae of these fishes develop properly only in fresh or slighly brackish water. Juvenile marine fishes are generally more tolerant of low and fluctuating salinites than adult fishes, therefore, estuarine and nearshore environments are usually dominated by juveniles (TRIGOM 1974). Salinity regimes vary constantly in coastal Maine (see chapter 5, "The Estuarine System"). Tidal flushing and freshwater inflow are the dominant regulators. People alter estuarine salinity through removal, impoundment, or addition of fresh water, and by altering water basin or channel configuration, which may change currents or alter tidal flow (table 11-6).

Competition

Fishes compete for food, space, shelter, and spawning sites with members of their own species (intraspecific competition) or other species (interspecific competition). Competition is density-dependent; that is, it is governed by numbers of individuals present in a certain area and the availability of habitat. People sometimes increase competition in natural communities by limiting available habitat and food supply and by introducing competing species.

Table 11-6. Human Activities That Potentially Influence Fish Abundance and Distribution

Activities	Food availability	Habitat availability	Mechanical injury	Obstruction to migration	Harvest/removal	Temperature	Salinity	Dissolved oxygen	Turbidity	Pathogens/disease	Radioactivity	Toxicants	Nutrients	pH
	Factors of Abundance and Distribution													
Agriculture[a]	X	X				X	X	X	X			X	X	
Forestry	X	X				X		X	X			X	X	
Fishing	X		X		X									
Power generation[b,d]														
Nuclear	X	X	X	X	X	X	X	X	X		X			
Fossil fuel	X	X	X	X	X	X	X	X	X			X		X
Hydroelectric	X	X	X	X	X	X	X	X	X					
Transportation[c,d]	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Industrial and Municipal Waste Disposal	X	X		X		X	X	X	X	X	X	X	X	X
Dredging	X	X					X	X	X			X	X	

[a] Includes applications of biocides and fertilizers, erosion and runoff problems.
[b] Impacts are dependent on design and mode of operation.
[c] Includes spills.
[d] Includes impacts associated with construction.

Predation and Harvest

Predation is another important interaction among individuals of the same or different species. Predation, including harvest by people, influences the number of individuals in a population. Fishes are preyed upon by marine mammals, seabirds, wading birds, terrestrial birds, terrestrial mammals, waterfowl, and other fishes. Harvest by humans, specifically over-harvest, has had historic impacts on fish populations (see "Importance to Humanity," this chapter). People affect predation by stocking prey and predator species. Predation is essential for population regulation and must be wisely considered in management decisions. Human predation (harvest) limits must be maintained so as to allow for natural regeneration, during which only excess individuals should be harvested.

Diseases and Parasites

Fishes are subject to a wide variety of diseases and parasites, including viral, fungal, and bacterial infections, and parasitic protozoans, worms, crustaceans, and sea lampreys. Deficiency and degenerative diseases, such as cancer, rickets, blindness, and liver dysfunction, are common. Fish populations in the wild usually are not impaired seriously by disease and parasites and epidemics are rare.

Hatchery fishes, however, are very susceptible to large scale infestations and may serve as carriers to the wild. Furunculosis (*Bacillus salmonicida*) is a disease that has spread from hatchery reared salmon to natural populations (Clayton et al. 1976). Disease can be a significant limiting factor in recovering populations. The market value of some species (cod, for example) is diminished by the presence of parasites. The problems and possible mechanisms of "codworm" infestation are discussed in chapter 13, "Marine Mammals." Diseased or parasite-carrying fishes may be more susceptible to other causes of mortality. People increase fish exposure to disease-causing agents and parasites, primarily through disposal of wastes in waters (table 11-6). People also introduce potentially detrimental species to an area. The sea lamprey (a parasitic fish) was inadvertently introduced and became landlocked in the Great Lakes, where it has all but eliminated some of the commercial and recreational fisheries. Its habitats in Maine presently include the open ocean, coastal rivers, and their tributaries. There is as yet no evidence of harm to Maine's freshwater fish populations from sea lampreys (Everhart 1958).

Dams and Obstructions

Physical obstructions, such as water falls and artificial dams, dikes and weirs, are barriers to migrating fishes. The majority of the existing dams in the coastal zone are impassable for many anadromous fishes (American shad, Atlantic salmon, alewife, sturgeon, and blueback herring), and many resident migratory freshwater fishes (e.g., trout). Young of the catadromous eel (elvers) can surmount most of these barriers (personal communication from C. Walton, Maine Department of Marine Resources, Hallowell, ME; May, 1978). Dams with heights as low as 2 feet (0.6 m) can be effective barriers at low water levels.

Data on the distribution, height, and condition of impoundments in the Maine coastal zone show that of the 176 surveyed impoundments, only 20 were equipped with fish passage facilities. These dams caused much of the decline of anadromous fish runs in Maine. Over 20 rivers in Maine originally supported Atlantic salmon runs; that number declined to less than 9 by 1960 (Everhart 1958). A recent report by the U.S. Army Corps of Engineers (1979) on the hydroelectric potential at existing dam sites in New England identifies a total of 276 dams (20% of the state total) in the characterization area. Nineteen of these dams are currently generating power, 56 are either partially breached or need total reconstruction, and 201 are existing structures currently in use for purposes other than hydropower. Of the 257 sites, 96 have a potential generating capacity greater than 50 kw at 40% capacity. These are the sites most likely to be developed first for hydroelectric power generation (see atlas map 4).

The problems dams present to migrating fishes are by no means eliminated by the installation of fish passage facilities. Most fish passage facilities aid upstream migrating fishes but provide little, if any, help to downstream migrating fishes and juveniles. Undirected, the downstream migrants follow the flow of water over spillways or through conduits and turbines. Mechanical and thermal mortality or injury often result. Where falls or spillways are of sufficient height to create fall velocities approaching 40 feet/sec or 12 m/sec (about 25 feet or 8 m of head), potential for damage to fishes exists (Bell 1973). Although this is not usually a major problem of low-head hydroelectric dam facilities, of the 256 existing nonhydroelectric dam sites in the coastal zone, at least 17 have a gross head greater than 25 feet. Also, fishes tend to concentrate at fish passage facilities (waiting to go up or down). This concentration increase their availability to anglers and they also may be easy prey for birds and other predators.

Fish passage facilities do not always work well. Fishway configurations vary in approach, length of run, slope, number and size of resting pools, water levels and flows, and velocities. Many species require special design features and it is difficult to build a fish passage facility that acommodates all sizes or species of fish. The ability of a fish to negotiate a fishway or ladder is highly dependent on its swimming speed and sensory behavior. Sturgeon do not successfully pass pool type fishways (Bell 1973). They must be moved via elevator (lock), be carried, or trucked over. There are no such facilities in Maine. Striped bass and rainbow smelt are also very reluctant to use many fishways (personal communication from B. Rizzo, U.S. Fish and Wildlife Service, Newton Corner, MA; November, 1979). All of the existing fish passage facilities in Maine are either Denil fishways or vertical slot type. These facilities are suitable for passage of Atlantic salmon, American shad, blueback herring, alewife, sea lamprey and most trout (personal communication from B. Rizzo, Ibid).

Water Quality

Aquatic environments are the eventual sinks for most wastes and pollutants. A number of water quality and water chemistry parameters have profound effects on fishes, and human activities have demonstrable effects on these parameters. These water quality parameters include turbidity, dissolved oxygen, pathogens, toxicants, radioactivity, nutrients, and pH. The major water quality problems in coastal Maine are described in chapter 3, "Human Impacts on the Ecosystem."

Turbidity. This is a measure of the amount of suspended solids in the water column. These solids are usually fine organic or inorganic materials. They are essential to biological processes as sources of nutrients but in excess can cause serious problems. Extreme suspended sediment loads may be of natural origin or due to human activities (dredging or spoil disposal, construction, agricultural, or timberland runoff). High levels of solids, as they settle, are a particular hazard to demersal eggs and the integrity of a spawning area in general. The main effects are direct and acute for eggs, young, and adults. The two major effects are interference with oxygen exchange (smothering) or clogging of fish gills (Clayton et al. 1976). The extent of harm due to settling of suspended solids depends on the type of material, time of year, and the species involved. Clay particles are apt to form a hard, compact crust upon settling. Organic materials, such as wood pulp fibers, can form an impenetrable mat over the bottom (Bell 1973). This can render a spawning area unusable and suffocate invertebrates (fish food). Silt may also contain toxic residues (from agricultural or industrial wastes), which may be lethal to local fishes or destroy fish food organisms. Excessive turbidity from organic wastes may seriously reduce the availability of oxygen through microbial action. Turbidity may also be caused by living material, such as plankton, usually in concentrations greater than 0.1% by volume (Bell 1973).

Suspended sediments in excess reduce the penetration of light into the water column which may reduce the populations of submerged vascular plants, phytoplankton, and algae. This decreases primary productivity and affects available food supply in the system. High turbidity is most common in sluggish waters near shore and in partly enclosed areas. In general the less mobile (demersal) fishes have a higher tolerance for turbid water but are also more heavily exposed as the sediment settles (Clayton et al. 1976).

Dissolved oxygen. Most fishes are adversely affected by reduced levels of dissolved oxygen (DO). Massive fish kills have been recorded as a result of severe oxygen depletion. Fish-kill data are not systematically maintained. Active, migratory fishes like the blueback herring, alewife, and menhaden, have high oxygen demands and are particularly sensitive to dissolved oxygen sags. For most cold water fishes (e.g., salmon and trout) it is desirable that DO concentrations be at or near saturation levels (Bell 1973). Certain human activities increase the oxygen demand in aquatic systems. Additions of organic wastes, nutrients, and sediments increase the levels of microbial decomposition, which consumes oxygen. Dissolved oxygen reductions are more often a problem of sluggish, impounded, or enclosed waters. Temperature also affects DO levels: higher temperatures decrease DO levels.

Pathogens. A wide variety of pathogens, in the form of bacteria, protozoa, viruses, and fungi, may enter aquatic systems from municipal waste disposal activities or accidental spills. Chronic disturbances, such as municipal sewage, may permit the population to remain in place but cause morbidity, such as fin rot or other diseases (Clayton et al. 1976).

Toxicants. Heavy metals, hydrocarbons, biocides, and industrial chemicals are particularly hazardous and lingering toxicants. Effluents from industrial plants and mines may contain heavy metals (e.g., copper, mercury, cadmium, selenium, silver, mercury, lead, zinc, and iron) in concentrations that are lethal to fishes or their food organisms. These elements can accumulate in fish tissue over time. Chronic, insidious effects occur as these elements enter the aquatic food chain. Some become concentrated in organisms, and are transferred from prey to predator (biological magnification). Certain combinations of metals (such as cadmium and zinc, copper and zinc, selenium and zinc) exhibit compounding effects. This factor must be considered when they are found in combination. The reactivity of these metals, and other toxic compounds, is affected by pH. Analysis of fish tissues from Maine has shown unusually high mercury content, for unexplained reasons (personal communication from A. Julin, U.S. Fish and Wildlife Service, Newton Corner, MA; January, 1980). In many cases, natural sources are suspected.

Fuel oil, kerosene, and other hydrocarbons are directly toxic to plants and animals. They enter water bodies through spills or as industrial wastes and can be present throughout the water column and on the bottom. The shoreline (intertidal) zone is most heavily and persistently damaged by nearshore oil spills (Canada Department of Environment 1974; and NOAA 1978). The occurrence of oil spills in Maine is documented in chapter 3, "Human Impacts on the Ecosystem." Fishes, especially flounder, accumulate petroleum hydrocarbons in their tissues. Up to 97% of the cod and pollock embryos collected from the area of the Argo Merchant ship oil spill in 1976 were dead, dying, or malformed (NOAA 1978). Tainted fish flesh, caused by exposure to soluable petroleum components, make fish unmarketable. Bowman and Langton (1978) found that fishes did not avoid prey that were contaminated with oil. Sinderman (1978) summarizes the effects of oil on marine organisms based largely on laboratory toxicity studies. Sub-lethal and behavioral effects include inhibition of mating responses, reduced fecundity, chromosomal abnormalities in eggs, abnormal larval development, and decreased feeding activities.

Biocides include both pesticides and herbicides. Chronic and acute toxicities of a given compound vary with environmental factors, such as water temperature and water chemistry, and biological factors, such as age, sex, size, condition, and species of fishes involved. The most hazardous biocides are those that are persistent in the environment (have low biodegradability). This is common of the chlorinated hydrocarbon pesticides, such as DDT and Dieldrin, and polychlorinated biphenyls (PCBs). They can remain in sediments unchanged for many years. Many animals, including fishes, take up these chlorinated hydrocarbons that are present in water at sublethal levels and store them in their fatty tissues. Assimilation takes place both in feeding and in direct assimilation from the water. Death can occur when food supply is restricted and the animals use their body fat for energy. Equally disasterous is the mobilization of the contaminated body fat in reproduction. The transfer of toxicants may inhibit normal development of the young in this way (Bell 1973).

Fishes may build up pesticide residues in their body tissues gradually without apparent ill effect, but other animals preying upon contaminated fishes may be killed or damaged by the concentrated toxicants. The establishment of controls for safe levels of applications of these biocides requires consideration of these food chain accumulation and storage phenomena. Pesticides can affect fish populations indirectly by eliminating food items. The other group of pesticides, the organic phosphates (e.g., Sevin, Orthene, Sumithion, Metacil, and Dylox) are generally less toxic than the chlorinated hydrocarbons and usually persist for less than one year. A number of studies have looked at the impacts of those insecticides used in the spruce budworm control program (Rabeni 1978; U.S. Forest Service 1976; and Gibbs 1977). Many herbicides (e.g., toxaphene, inorganic sulfates, endothal, diquat, hyamine, delapon, silvex, and 2,4-D) at high concentrations have toxic effects on fishes (Workman and Neuhold 1963; Surber and Pickering 1962; McKee and Wolf 1963; Jones 1964; Cope et al. 1970; and U.S. Department of Agriculture 1968). Toxicants in fish have not been a serious problem in Maine.

Radioactivity. The exposure of plants and animals to radioactivity should be avoided. Radionuclides in aquatic environments may affect fishes through direct radiation from the water or accumulated sediments. Radioactivity may be absorbed onto skin, through cell membranes, or ingested with food and water. The major route of accumulation appears to be through consumption of food organisms (mostly filter feeders) which already have high concentrations of radionuclides from the waters around them. Radioactive elements and compounds enter aquatic systems through natural fallout, release of wastes from nuclear users, and accidental spills. Concentration and accumulation of radionuclides in mussels has been documented in the vicinity of a nuclear power plant in Plymouth, Massachusetts (personal communication from A. E. Eipper, U.S. Fish and Wildlife Service, Newton Corner, MA.; December, 1979). Radiation has not yet been a problem to the fishes of Maine.

Nutrients. Raw materials essential to biological organisms are called nutrients. Excess nitrogen (in the form of nitrates) and phosphorus (in the form of phosphates) can lead to eutrophication in aquatic systems, enhancing the growth of primary producers (e.g., algae). Blooms of these plants create acute problems for fishes. As the bloom dies, deoxygenation occurs through microbial action and creates a lethal environment for organisms requiring high oxygen content. Chronic effects may include the eventual dominance of the area by species more tolerant of low dissolved oxygen levels. Excess quantities of nutrients are sometimes introduced through waste disposal, runoff from agricultural and timber lands, and accidental spills (see chapter 7, "The Lacustrine System," and chapter 3, "Human Impacts on the Ecosystem").

pH. Freshwater systems with low buffering capacity are very sensitive to changes in the pH (a measure of acidity or alkalinity). Marine waters are highly buffered by salts and carbonates, and pH is relatively uniform. Acid precipitation is lowering the pH (increasing the acidity) of lakes and streams in the northeastern U.S., including Maine, at an alarming rate (see chapter 3, "Human Impacts on the Ecosystem"). Natural rainfall should have a pH near 5.7. Some species (e.g., most trout) are seriously impaired or killed at pH levels below 5.0. The pH of precipitation in the northeastern U.S. now ranges between 2.1 and 5.0 (Likens and Bormann 1974). Complete losses of fish populations due to acidification have been reported in the Adirondacks region of New York State (Schofield 1977) and Ontario, Canada (Beamish and Harvey 1972), and other areas. Symptoms of the acidification included poor recruitment, failure of females to produce viable eggs, and high mortality or abnormalities of eggs and larvae. Reactivities of certain toxic elements and compounds in sediments are affected by pH. For example, aluminum, copper, and mercury, are released by sediments at lower pH levels. The major causes of acidification are: combustion of fossil fuels in power generation, and transportation and subsequent production of sulfuric and nitric acids in the atmosphere. The problem of acidification can only worsen as consumption of fossil fuels increases.

IMPORTANCE TO HUMANITY

The importance of fishes to humanity extends beyond their role in the energy flow of aquatic food webs. As a renewable resource, fishes are important to humans as food and industrial products, for recreation and sport, and as biological indicators of environmental problems. They also provide opportunities for scientific and educational studies in natural history, evolution, and resource management.

Maine lands about 30% of the total catch of New England's commercial fishery and is second only to Massachusetts in total fish landed. Catch statistics for the last century are presented in table 11-7. From 1887 to 1931 the annual catch ranged from 123 to 242 million pounds and adveraged 144 million pounds. Between 1932 and 1940, annual landings ranged from about 67 million pounds (1938) to 116 million pounds (1938) and averaged only 96 million pounds. From 1942 to 1968 average annual landings increased to 245 million pounds and total landings ranged between 134 million pounds (1943) and 356 million pounds (1950). Average and total landings declined again for the years 1969 to 1977, showing a range between 138 and 178 million pounds and a yearly average of 151 million pounds.

The most important commercial species in the last decade, in order of abundance, were herring, redfish, whiting, menhaden, cod, pollock, red and white hake, mackerel, alewife, flounder, haddock, cusk, and eel (table 11-8). One hundred years of commercial landings statistics for major species are given in table 11-9. Herring and redfish landings remain at the top both in catch quantity and in dollar value. Similarly, alewife remain a steady 6th and 7th on the list. Cod landings now are again on the increase. The haddock catch declined after the mid-1930s, rebounded some in the 1950s, and again declined in the late 1960s. Data from the last 2 years suggest that the haddock catch is on the increase. Pollock catches picked up betwen 1940 to 1960, showed a great drop during the 1960s, and now appear to be on the increase (1974 to 1977). Whiting (silver hake) made a sudden appearance in the commercial market, ranking third in catch quantity for the years between 1939 and 1973. Menhaden is another species making a sudden appearance among the top seven (1973 to 1977).

Landing points do not always represent areas of capture and undetermined amounts of Maine catches are landed at ports in Canada, Massachusetts, and New Hampshire, and vice versa. Trends in landings of principal species (tables 11-8 and 11-9) reveal fluctuations and shifting emphases in response to fish abundance, market demand, gear efficiency, fishing effort, and foreign fishing. General declines in abundance are often unperceived statistically until well into the declining period. Intensified fishing effort and the utilization of more selective gear tend to counterbalance apparent catch shortages.

Table 11-7. Landing Statistics (pounds and dollar values) for Maine Fisheries, 1879 to 1976[a].

Year	Pounds (1000 lb)	Value ($1000)
1880	NA[b]	2742
1887	131,380	2365
1888	132,930	2292
1889	129,560	2111
1898	123,405	2655
1902	242,390	2919
1905	124,724	2386
1908	173,843	3257
1919	147,956	3889
1924	116,707	4137
1928	123,326	4231
1929	162,940	4897
1930	143,824	4329
1931	116,236	3443
1932	90,602	2413
1933	98,498	2308
1935	112,219	3309
1937	101,179	2806
1938	67,206	2521
1939	116,167	2695
1940	88,088	2607
1942	168,392	5229
1943	133,920	7010
1944	161,285	7053
1945	184,425	12,499
1946	195,955	14,142
1947	220,868	12,870
1948	303,504	16,077
1949	294,297	14,988

[a]NMFS, Maine Landings.
[b]not available.

(Continued)

Table 11-7. (Concluded)

Year	Pounds (1000 lb)	Value ($1000)
1950	356,266	14,688
1951	223,051	15,606
1952	298,151	17,897
1953	243,513	16,754
1954	285,736	16,856
1955	257,174	16,083
1956	279,562	16,966
1957	292,250	16,769
1958	316,955	19,024
1959	265,958	19,571
1960	294,641	20,071
1961	197,970	19,029
1962	294,323	20,365
1963	285,636	21,216
1964	192,575	21,958
1965	204,846	21,922
1966	200,392	24,329
1967	197,438	22,973
1968	218,731	25,614
1969	191,314	27,533
1970	158,806	30,672
1971	142,684	31,129
1972	149,271	34,817
1973	143,319	43,061
1974	147,822	41,410
1975	138,360	48,499
1976	177,835	53,822

Table 11-8. Landings (pounds) and Value (dollars) of the Major Commercial Fish Species in Maine in 1977[a]

Species	Rank	and pounds (1000s)	Rank	and dollars (1000s)	Utility	Recent catch trends
Herring	1	73,050	1	3545	Food and industrial	Increasing
Redfish	2	20,801	2	3140	Food	Increasing
Pollock	3	10,685	5	1406	Food	Increasing
Cod	4	9126	4	1974	Food	Increasing
Flounder:species	5	8272	3	2869	Food	Increasing
Red & white hake	6	6600	7	744	Industrial	Increasing
Alewife	7	3374	10	120	Industrial	Fluctuating/ increasing
Menhaden	8	3289	12	71	Industrial	Fluctuating/ decreasing
Haddock	9	2250	6	960	Food	Increasing
Cusk	10	1000	9	163	Food	Increasing
Mackerel	11	330	11	77	Food	Fluctuating
Whiting (silver hake)	12	225	13	17	Food and industrial	Decreasing
Eel	13	176	8	263	Food and industrial	Fluctuating

[a]Lewis 1979.

Table 11-9. Landings (Pounds X 1000) of Major Commercial Fishes from 1880 to 1977[a]

Year	Alewife	Cod	Cusk	Flounder	Haddock	Red + White hake	Herring	Mackerel	Menhaden	Redfish	Pollock	Whiting
1880	NA	56,004	NA	NA	17,729	24,448	34,695	31,694	NA	----	NA	----
1887	2526	45,020	676	659	8901	14,060	33,570	5568	702	----	2684	----
1888	2836	40,252	715	829	8659	14,948	40,802	2087	3125	----	3375	----
1889	4022	29,017	675	829	7809	13,333	32,156	1176	10,185	----	4256	----
1892	2276	----	----	----	----	----	40,814	5072	83	----	----	----
1896	3388	----	----	----	----	----	----	----	----	----	----	----
1897	1249	11,487	1168	NA	6112	9290	45,667	2674	229	----	2376	----
1898	3619	20,556	1312	787	9188	18,141	46,596	1661	7660	----	3132	----
1902	3341	23,878	2651	569	7364	20,726	165,136	1840	252	----	6419	92
1905	3082	12,261	1675	97	8785	15,309	65,926	917	----	----	3363	124
1908	2085	20,013	2078	31	10,513	17,398	92,985	380	----	----	8941	25
1919	1296	15,062	1046	470	11,271	16,118	86,979	604	----	----	5667	691
1924	1583	22,443	1569	343	15,559	11,724	47,930	2310	1	----	2878	70
1928	2132	16,187	960	1175	12,204	7681	64,685	1596	----	----	2876	4
1929	2821	17,661	1281	1570	14,539	10,074	91,860	3999	----	4	2217	3
1930	2129	13,484	1354	1950	12,508	11,685	73,939	3042	----	10	2045	41
1931	2796	12,653	1387	1328	11,694	5644	55,785	5422	----	2	1880	6
1932	2296	12,105	1029	867	9799	6172	31,988	7661	----	2	1997	3
1933	1703	9337	1584	1179	9307	7084	43,775	4499	----	47	3006	----
1935	3374	8407	2734	1669	4245	16,232	50,943	1477	----	140	5018	12
1937	2818	7050	1553	2051	2837	7797	49,952	1544	----	569	6700	NA
1938	3140	6221	1506	1815	2509	9048	16,055	1980	----	4585	5920	648
1939	2954	3327	1724	1149	1941	5808	69,603	1947	----	7036	3223	4046
1940	2260	3188	1567	1719	2585	6414	38,017	1851	----	NA	3300	4036
1942	2368	4940	593	1934	4360	6973	93,997	1844	----	26,847	2876	2634
1943	3432	6320	371	2150	1893	8236	57,190	799	----	25,654	2237	1962
1944	2526	5573	382	2851	1986	6658	82,107	2014	----	26,555	2987	3836

[a]NMFS, Maine Landings.
[b]not available

(Continued)

Table 11-9. (Concluded)

Year	Alewife	Cod	Cusk	Flounder	Haddock	Red + White hake	Herring	Mackerel	Menhaden	Redfish	Pollock	Whiting	Eels
1945	1358	6924	388	1935	2321	6946	92,590	2109	9	28,352	5789	5289	
1946	1225	7395	824	2596	2815	8418	80,107	3052	----	41,072	7098	5697	
1947	1499	4595	601	1708	3540	4358	121,317	1690	14	39,988	4738	6015	
1948	1868	6386	1014	2314	6051	5574	182,461	4092	24	49,041	6300	8655	20
1949	3281	6075	1359	2300	7185	5713	149,894	3352	5027	55,503	6387	12,580	42
1950	3166	6613	1577	4560	7442	6118	185,481	4108	490	79,281	6950	15,616	38
1951	3479	5293	1382	6032	5267	3845	59,738	1531	1514	73,942	5972	19,577	53
1952	2783	4614	1216	4714	6108	4186	144,661	1925	605	60,468	7052	23,328	42
1953	2443	3769	1010	4098	5391	4600	100,587	1022	2184	60,623	5634	12,668	40
1954	3296	3689	802	4144	5555	3788	123,602	472	5876	79,671	4529	9319	11
1955	3779	2863	673	3533	4566	2831	99,416	1011	4016	67,685	5416	25,128	33
1956	4588	2746	442	3192	4904	3187	140,472	481	1216	64,967	5586	14,835	29
1957	3969	2352	584	3073	4667	2870	153,621	257	273	64,723	3719	15,810	20
1958	3095	2735	542	2526	3997	2088	170,977	513	----	71,068	4364	23,577	21
1959	1631	2694	595	2121	3405	1810	117,150	531	----	72,225	3689	23,339	17
1960	1412	2897	578	1952	3834	3033	152,327	301	35	78,258	3975	11,123	30
1961	1667	2507	600	1483	2940	2731	54,463	153	----	77,350	3206	14,147	32
1962	1682	2260	609	1205	2545	3277	156,699	40	----	69,453	2569	17,832	35
1963	1480	1960	470	1216	2877	3564	152,317	304	----	63,905	2489	15,942	37
1964	1480	2400	371	1153	2948	3554	60,866	488	----	58,936	1312	25,304	23
1965	2706	2629	286	1333	1881	3849	70,180	669	----	60,307	1093	27,722	52
1966	1786	2802	303	1402	1773	2018	58,299	690	----	65,082	1076	29,699	49
1967	1617	3496	194	1462	2351	1413	64,600	353	----	62,154	1095	20,726	49
1968	2249	5037	131	1434	1790	1255	69,703	388	----	57,750	1398	28,916	65
1969	1768	4617	135	973	983	1048	54,214	248	----	50,752	1212	17,890	38
1970	1623	5427	266	1023	1013	1411	36,583	482	----	46,688	811	14,837	38
1971	1954	4379	309	1258	821	1972	28,572	225	----	46,630	890	9900	54
1972	2216	4432	432	2078	491	2949	44,690	92	----	42,748	1326	4095	70
1973	2691	4035	577	2419	352	2140	37,229	379	6936	36,092	2357	5517	76
1974	3310	4004	632	1732	229	3778	47,398	284	10,149	30,626	3594	2869	79
1975	3768	5596	801	2712	776	4559	38,247	145	13,958	21,514	5917	1198	155
1976	3395	6367	862	3610	1537	5524	70,233	405	17,553	20,783	7717	408	191
1977	3374	9126	1000	8272	2250	6600	73,050	330	3289	20,803	10,685	255	176

A very important factor in recent catch trends is the adoption of the 200-mile (320 km) limit to foreign fishing. Since its implementation in March of 1977, substantially fewer foreign vessels are fishing the waters off the east coast of the United States. This has resulted in increased availability of many species to American fishermen. According to the National Marine Fisheries Services (NMFS) figures, the overall landings of all species at 8 New England ports between January and April of 1977 increased by 15 million metric tons over the 83 million tons taken in 1976 (Lyman 1977).

Sport fishing is one of the oldest forms of human recreation and is enjoyed by many. The mean annual number of sport fishing licenses issued in Maine between 1968 and 1971 was 240,512. An average of 145,678 of these were sold to Maine residents annually during those years, which amounts to about 15 licenses per 100 people (MDIFW 1976). The major sport species inhabiting the characterization area are listed in table 11-10. The catch for some sport species in Maine waters, e.g., bluefish and striped bass, rivals or exceeds their contribution to the commercial catch (Chenoweth 1977). The 200-mile (320 km) limit probably has affected marine sport fishing as well. Since its implementation in 1977, estimates of cod and pollock catches in New England by recreational anglers have nearly doubled, but the cause has not been established (Lyman 1977).

Human activities (e.g., operating dams, log-holding ponds, and hydro-powered mills) on and along the waterways of Maine have had damaging impacts on both inland and anadromous fisheries. Efforts to improve and install fishways and the elimination of river log drives have aided the restoration of many species in several rivers. The Atlantic salmon is the fisher's prize and probably best known. In 1972 along the west branch of the Penobscot River, fishing opportunities greatly increased with the end of Great Northern Company's pulpwood drives. The halting of log drives on the Kennebec River in 1976 should contribute to the recovery of that river's fishery. The Penobscot River (Bangor Salmon Pool) and the Machias River reported "record-breaking" rod catches of salmon in 1978. The removal or breaching of dams along these waterways was a major factor contributing to these increases. The Dennys River, one of Maine's smaller coastal river systems and well known for its Atlantic salmon, landlocked Atlantic salmon, and smallmouth bass, has also shown increased catches for the 1970s. According to Atlantic Salmon Commission records, more than 800 salmon were reported taken in Maine in 1978. As of August 1979, rod and trap catches were less than half of that. There is considerable debate over the cause of these poor 1979 returns. Contributing factors may be the extremely poor survival of young salmon (smolts) migrating down to the sea in the spring of 1977. In August, 1979, fishing for Atlantic salmon was officially halted for the season statewide.

MDIFW (1976) provides detailed information on existing access for anglers and on the distribution, abundance, present and projected angler use of landlocked Atlantic salmon, brook trout, brown trout, lake trout, rainbow trout, rainbow smelt, lake whitefish, chain pickerel, white perch, and smallmouth and largemouth bass. Brown trout, rainbow trout, and smallmouth and largemouth bass are not native to Maine (their introductions date back to the late 1860s) but they comprise a major fishery today. MDIFW has stocked a number of lakes and ponds with brown trout, brook trout, largemouth and smallmouth bass, landlocked Atlantic salmon, lake trout, alewife, rainbow trout, sunapee trout, and chain pickerel (see appendix table 10, and "Management" in this chapter).

Table 11-10. Major Sport Fishes of the Characterization Area[a]

Group and common name	Taxonomic name
Marine	
Bluefish	Pomatomus saltatrix
Atlantic cod	Gadus morhua
Atlantic mackerel	Scomber scombrus
Winter flounder	Pseudopleuronectes americanus
Shark	Squalidae sp.
Pollock	Pollachius virens
Redfish	Sebastes marinus
Anadromous	
Atlantic salmon	Salmo salar
American shad	Alosa sapidissima
Alewife	Alosa pseudoharengus
Striped bass[b]	Morone saxatilis
Rainbow smelt	Osmerus mordax
Freshwater	
Coldwater	
Landlocked salmon	Salmo salar sebago
Brook trout	Salvelinus fontinalis
Lake trout	Salvelinus namaycush
Brown trout	Salmo trutta
Rainbow trout	Salmo gairdneri
Lake whitefish	Coregonus clupeaformis
Warmwater	
Chain pickerel	Esox niger
White perch	Morone americana
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides

[a]Foye (1969); MDIFW (1976); Chenoweth (1977); Meister and Foye (1963).
[b]Anadromous, but does not spawn in Maine.

As biological indicators, fish are useful in helping to predict, solve, and avoid many ecological problems. Insight into the general effects of toxic substances can be determined through bioassay and bioaccumulation studies on fishes. Their utility as indicators, however, has intrinsic problems. Because of their mobility, the strict presence or absence of a particular fish species is not always a reliable indication of the quality of the local habitat. Too little is known about seasonal and long-term natural cycles and their influence on fish populations to determine definite cause and effect relationships. The impact of an acute perturbation, such as an oil spill or massive dissolved oxygen sag, may be clear but a particular fish's response to a chronic perturbation may not be evident for a long time, if at all. A less mobile, low-level consumer organism, such as a benthic invertebrate (e.g., mussel, clam, and oyster) is, in most cases, a better indicator of habitat "quality".

MANAGEMENT

Although it is beyond the scope of this characterization to make management recommendations for the fisheries of the Maine coast, this section is intended to introduce the reader to existing management authorities and to describe current management plans. A detailed account of the regulatory processes (Federal and State) and emerging management technologies associated with marine resource conservation was prepared by Chenoweth (1977).

The following agencies contribute to the development of management policy for the various fisheries in the Maine coastal zone:

1. Maine Department of Inland Fisheries and Wildlife (MDIFW)
2. Maine Department of Marine Resources (MDMR)
3. New England Regional Fisheries Management Council
4. Maine State Legislature
5. Atlantic Sea Run Salmon Commission
6. National Marine Fisheries Service
7. U.S. Fish and Wildlife Service

The authority of the State of Maine over its fishery resources extends outward to 3 miles from the coast. Within this boundary the Maine Legislature has authority to initiate management policy through legislation. Policies are adopted through legislative action upon recommendations from resource agencies (MDIFW and MDMR), the fishing industry, sportsmen's groups, environmental groups, and others.

The Commissioner of the Maine Department of Inland Fisheries and Wildlife authorizes research and establishes management regulations for the freshwater fisheries and wildlife resources within the State. The MDIFW sponsors statewide biological surveys of the lakes, rivers, and streams. They describe the major problems associated with the management of freshwater and anadromous fisheries in the major stream systems. These reports discuss the history, status, and potential of the major fisheries and evaluate specific management alternatives. MDIFW and the Atlantic Sea Run Salmon Commission are currently preparing updates on those original biological surveys, addressing fish restoration and management in major stream systems. Recently the MDIFW, taking the initiative in planning for Maine's fish and wildlife resources, has compiled species assessments and developed strategic plans for the management of the following inland fisheries: landlocked Atlantic salmon, brook trout, lake trout, brown trout, rainbow trout, rainbow smelt, lake whitefish, chain pickerel, white perch, smallmouth bass, and largemouth bass (MDIFW 1976).

The Commissioner of The Maine Department of Marine Resources has the authority to "investigate conditions affecting marine resources" and to establish regulations that "promote the conservation and propagation of marine organisms within Maine's coastal waters." For jurisdictional purposes, coastal waters are defined as "all waters of the State within the rise and fall of the tides and within the marine limits of the jurisdiction of the State" (Marine Resources Laws and Regulations, Revised to January, 1979). The Commissioner authorizes research and administers and enforces all laws that apply to the marine and estuarine resources of the State, with the exception of Atlantic salmon, which is under the authority of the Atlantic Sea Run Salmon Commission.

Maine Department of Marine Resources conducts extensive biological research programs that contribute to the development of comprehensive fish, wildlife, and marine resource management recommendations. In particular, the MDMR has published management recommendations for the alewife, American eel, and striped bass resources, addressing the history, status, and future of these fisheries (Walton 1976; Flagg 1976; and Ricker 1976).

The creation of the Atlantic Sea Run Salmon Commission by the legislature in 1947 authorized the enhancement of an anadromous sport fishery in the State of Maine. This agency evaluates, manages, and restores the fishery potentials of individual watersheds. Studies and investigations include stocking programs and population assessments.

The Federal Government assumes certain responsibilities or tasks in the management of many fishery resources because the migratory habits of certain species make them both interstate and international resources. These responsibilities are carried out by the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS). Both FWS and NMFS have an advisory role in the issuance of Federal permits for activities that may affect fish habitat.

Outside of waters on Federal lands, FWS has no management authority per se. FWS maintains programs of fishery research with the States for coastal anadromous fisheries and inland fisheries and reservoirs; it supports Cooperative Fishery Research Units; and it maintains a separate program to preserve, restore, and enhance endangered and threatened species. FWS also maintains Federal fish hatcheries, which provide fishes for State stocking programs.

NMFS is concerned with many aspects of marine fisheries, ranging from resource assessment to ultimate use by consumers. It is the lead research agency for marine resources and fisheries outside the State's territorial waters and maintains a commercial catch data base within its statistics and market news division. The Resource Assessment Division of the Northeast Fisheries Center of NMFS has completed stock assessment documents on the following commercially important species: herring, white hake, cod, squid, northern shrimp, silver hake, pollock, redfish, and haddock. NMFS funds State research through the Commercial Fisheries and Research Act (PL 88-309) and the Anadromous Fish Act (PL 89-304). It is also responsible for the enforcement of domestic fisheries regulations under the authority of the Conservation and Management Act (PL 94-265).

Prior to 1 January, 1977, marine resources in the waters outside a 12-mile (19 km) boundary (offshore fisheries) were under international control. These fisheries were regulated by joint effort of the nations participating in the International Commission for Northwest Atlantic Fisheries (ICNAF), of which the United States was a member. Regulations included minimum mesh-size in trawls, minimum length of fish caught, restriction of fishing by large trawlers over certain areas, seasonal closures of some areas for certain species, species quotas, total fish quotas, and international inspection schemes (Chenoweth 1977).

On 1 March, 1977, by act of Congress (Conservation and Management Act, PL 94-265), the United States declared management authority over all marine resources in an area between the 3-mile (5 km) limit of the States' territorial seas and a line 200 miles (320 km) from the territorial seas. In New England waters, the fisheries within the zone are to be regulated by the U.S. Department of Commerce, based upon policies established by the New England Regional Fisheries Management Council. The mechanism for establishing fisheries policy is the Fisheries Management Plan, which describes and analyzes the socioeconomic aspects of the fisheries, assesses the stocks for each major commercial species, determines the optimum yield from the fisheries, and recommends appropriate measures to obtain the optimum yield. The determination of optimum yield takes into account biological, socio-economic, and environmental factors.

Coordination of management strategies and regulation between the State of Maine and the New England Council will be necessary to effectively manage the stocks of several commercial species. The 3-mile (5 km) limit is a legal and not a physical boundary; fish move freely across it. Allowable catch levels and other regulations established by the State of Maine inside the 3-mile limit or by the Council outside the 3-mile (5 km) limit affect stocks on both sides. Enforcement of regulations on fishery utilization is effective only if coordinated on both sides. Coordination between States is also important. The species for which cooperative effort is most needed are Atlantic herring, silver hake, cod, haddock, yellowtail flounder, and pollock.

The key organizations involved in the development of fisheries management plans and their major inputs to the planning process are summarized in table 11-11.

RESEARCH NEEDS

Data on the relative biomass of fishes by habitat (system and class) are lacking. This information is very important in identifying and quantifying energy flows and productivities of different habitats by region and season.

Table 11-11. Major Roles of Agencies Involved in Fishery Management

Organization	Major input to planning and management					
	Statistical data bases	Biological & environmental data	Ecological impact assessment	Management recommendations	Management authority	Enforcement
Maine Department of Inland Fisheries & Wildlife	*	*	*	*		*
National Marine Fisheries Service	+	+	+	*		+
New England Regional Fisheries Management Council	+		+	+	+	
Maine Department of Marine Resources	*	*	*	*		*
Atlantic Sea Run Salmon Commission	*	*		*		
U.S. Fish & Wildlife Service		*	*	*	*	
Maine Legislature					*	

* = inside 3-mile boundary.
+ = outside 3-mile boundary.

Reproductive habits data and general life history information are still lacking for a number of common marine and freshwater fishes. This is especially true for fishes that presently have little commercial or sport value.

Stock assessment is of paramount importance in fishery management. Stock assessment technology has developed rapidly over the past few years; however, adequate data are lacking for many species (Brown 1976). The relationship between stock size and recruitment remains poorly defined for many species. More laboratory and field research is needed to understand the mechanisms of fish reproduction and how environmental factors influence the survival of fishes from egg to adult stages.

Data are needed on the trends and significance of environmental contaminant (pesticides, PCBs, and heavy metals) levels in fishes in the different drainages and rivers.

CASE STUDY: SHORTNOSE STURGEON

The shortnose sturgeon, Acipenser brevirostrum, is the smallest in the family of some 20 forms recognized worldwide and is a Federally listed endangered species. It is a moderate-sized (to 42 inches or 107 cm), slow-growing, long-lived (to 35 years or so), anodromous fish. According to Bigelow and Schroeder (1953), the shortnose sturgeon is scarce in the Gulf of Maine and there is no reason to think it has ever been more plentiful there.

Range and Distribution

The shortnose sturgeon ranges historically from New Brunswick, Canada, to Florida, typically in large tidal rivers such as the Potomac, Delaware, Hudson, Connecticut, and St. John. In Maine, shortnose sturgeon occur in the Sheepscot River (Fried and McCleave 1973), the Kennebec River, and the Penobscot River systems (personal communication from T. Squires, Maine Department of Marine Resources, Hallowell, ME; December, 1979). Information is scarce but there is evidence that shortnose sturgeon enter the sea and wander some distance from their parent stream (Bigelow and Schroeder 1953). It is not so strongly migratory as other species.

Reproduction and Growth

Very little is known about the spawning and early life history of the shortnose sturgeon; the young rarely are seen. Male shortnose begin to spawn at a total length of about 51 cm (20 inches) and females at 61 cm (24 inches). Reproduction occurs once every 3 years for individual females (Dadswell 1975). Spawning apparently occurs in the middle reaches of large tidal rivers from April to June, depending on location; adults apparently return to a parent stream (Scott and Crossman 1973). In the Connecticut River, eggs have been collected in late May near the river bottom when water temperature ranged between 15° C and 17.8°C or 59°F to 64°F (Clayton et al. 1976). Bean (1903) reported shortnose sturgeon spawning in the Delaware River in brackish or nearly fresh water in depths of 2m to 9 m (7 feet to 30 feet).

According to Scott and Crossman (1973), the eggs are dark brown, small, and less numerous per pound of fish than in other sturgeons. The eggs of a related species, the Atlantic sturgeon, are 2.5 mm to 2.6 mm in diameter, are demersal, and stick to submerged weeds and rocks. They apparently are broadcast with no parental care and hatch in 7 days at 17.8°C or 64°F (Clayton et al. 1976). The eggs of shortnose sturgeon hatch in about 13 days at 8°C to 12°C or 44°F to 54°F (Carlander 1969).

Shortnose sturgeon are slow growing. In the St. John River estuary, New Brunswick, Canada, shortnose sturgeon exhibited a growth rate of 1 to 3 cm/yr (0.4 to 1 inch/yr) although longevity was great (34+ years; Dadswell 1975). In the Hudson River, males mature at age V and females at age VI (Greeley 1937). Growth data for shortnose sturgeon captured in the Hudson River are (from Greeley 1937):

AGE	NO.	MEAN TL (mm)	MEAN WT. (gm)
III	3	480	766
IV	5	536	807
V	19	564	1,129
VI	12	615	1,469
VII	14	615	1,460
VIII	8	653	1,660
IX	4	795	3,098
X	3	732	2,150
XI	4	678	1,955
XII	3	787	3,093
XIII	4	665	1,941
XIV	2	711	2,622

Food and Feeding Habits

Shortnose sturgeon are bottom feeders. Hudson River specimens (young sturgeon) fed upon sludgeworms, chironomid larvae, small crustaceans, and some plant material. In the St. John River estuary, shortnose sturgeon feed on molluscs primarily, while a specimen in the Connecticut River was found to prey upon burrowing mayfly larvae principally; ostracods, caddis flies, oligochaetes, seeds, wood, and sand were also found in its stomach (Clayton et al. 1976).

Young and adult shortnose sturgeon alike compete for food with other bottom feeders such as suckers, but their random, suctorial feeding habit may have some advantage over the many species of fishes that browse on individual bottom organisms in the same turbid rivers (Scott and Crossman 1973).

Predation

Little is known of the predators of shortnose sturgeon, or the magnitude and effect of predation on their populations. Even the young fish may be protected from predation by their bony plates (Scott and Crossman 1973). The major predator on shortnose sturgeon may be people.

Importance to Humanity

The shortnose sturgeon is considered too small, and its populations too low, for extensive commercial use. As a declared endangered species it cannot be legally harvested or molested for any purpose. In the past, however, the worth of its roe and flesh was even greater than that of the Atlantic sturgeon (Clayton et al. 1976). Industrial and domestic pollution, obstruction of spawning grounds (e.g., dam construction), and overfishing probably account for the decline in sturgeon stocks.

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Chapter 12 Commercially Important Invertebrates

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Over 1500 benthic (bottom dwelling) invertebrate species live in the marine and estuarine systems of Maine. The most important phyla, in terms of numbers of species and individuals represented, are Mollusca (snails and clams), Annelida (principally polychaetes), and Arthropoda (primarily crustaceans).

These three phyla are important consumers that feed on the direct (phytoplankton and macroalgae) or indirect (detritus and animals) products of primary production and convert them into animal protein. The energy generated is passed on to higher trophic levels through predation (by fish, birds, other invertebrates, and humans). Detritus is colonized by bacteria and becomes a major food source for some invertebrates (deposit feeders). Also, the burrowing and feeding activities of invertebrates, particularly annelids, release sediment nutrients into the water column.

Species of molluscs, arthropods, and annelids live in the subtidal and intertidal zones (these zones are defined in chapter 4, page 4-59) of the marine and estuarine systems. Molluscs and arthropods are found on all bottom types whereas annelids are more common on unconsolidated bottoms. Some adult arthropods and annelids move into the water column during periodic migrations. Many of the species in these phyla have pelagic (living in the water column) larvae and, as such, are part of the water column habitat.

The sensitivity of species of these phyla to environmental variation and perturbations varies considerably. Some crustaceans are particularly sensitive to environmental change, but some polychaetes are very resilient. Intertidal invertebrates tend to be less sensitive to environmental impacts than subtidal invertebrates. Although landings of commercial forms may fluctuate greatly, they are generally less sensitive to habitat alteration than other invertebrates. The choice of a species as a biological indicator depends on many factors, including the type of variation or perturbation, natural life cycle events, natural predation, and in the case of commercial species, potential changes in abundance due to overharvesting.

Nine species from these phyla are discussed in this chapter. They were chosen for the following reasons: they represent a relatively large proportion of the overall benthic invertebrate production due to their abundance, size, and widespread availability (i.e., found along much of the Maine coast); in combination with fish, they are the basis of Maine's commercial fishery, and sufficient information about them is available to develop meaningful accounts.

The species selected are: (1) molluscs--soft-shell clam, blue mussel, and sea scallop; (2) crustaceans--lobster, jonah crab, rock crab, and northern shrimp; and (3) polychaetes--bloodworm and sandworm. The distribution of commercially harvested shellfish and marine worm areas is shown in atlas map 4.

These species accounts for coastal Maine describe distribution and abundance, life history, habitat preference, factors of abundance, importance to humans, human impacts, and management. Data deficiencies and research recommendations for the nine species named are given at the end of this chapter. In addition, the red tide organism, Gonyaulux excavata, is discussed below. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

SOFT-SHELL CLAM (Mya arenaria)

The soft-shell clam is a bivalve that lives in sediment at both intertidal and subtidal levels in estuaries and coastal regions of the ocean. This clam is a hardy species and is found in a wide range of salinities, temperatures, and sediment types. It tolerates long periods of ice cover as demonstrated in Denmark (Rasmussen 1973) and is capable of anaerobic respiration (Newell 1970), which means it can survive for limited periods of time in the presence of little or no dissolved oxygen. Clams are harvested in abundance by commercial clam diggers and, to a lesser extent, by the general public for private use.

Distribution and Abundance

In the Atlantic Ocean, the range of the soft-shell clam extends from Labrador to North Carolina and from Norway to France. It also occurs on the northern Pacific coast. Greatest abundance, based on commercial landings, occurs on the northeastern coast of the United States, particularly in New England and Maryland. Clams are nonmigratory and in favorable habitats occur in high densities. Commercially harvested clam flats are depicted in atlas map 4.

Life History

The soft-shell clam usually reproduces annually in Maine and semiannually south of Cape Cod. Sexual maturation of the individual depends on growth rate (i.e., the faster the growth, the earlier the maturation) but usually occurs in approximately one year (personal communication from L. L. Loosanoff, 17 Ceross Drive, Green Brae, CA; November, 1973).

In western Maine the species spawns during May to September, but along the eastern coastline, they spawn from early June to mid-August. The warmer water temperatures, which also occur earlier and for longer periods of time in western Maine, apparently account for the differences. The factors that trigger spawning have not been clearly defined, although spawning has been induced in culture by cyclic fluctuation in water temperature (Stickney 1964a).

Approximately 3 million eggs a year can be produced by a clam that is 2.4 to 3.2 inches (60 to 80 mm) in length. Gametes are released into the water through the exhalant siphon. Larvae are pelagic for 12 days in laboratory conditions (Stickney 1964a) and perhaps longer in natural conditions. In nature the larvae are subjected to the biotic and abiotic stresses of the pelagic environment. They are also carried by water currents, which ultimately determine their distribution.

After about 2 weeks the larvae undergo metamorphosis and attach to the sediment surface by byssal threads. Upon attachment the animals are considered juveniles. Growth in the first summer ranges between 0.2 and 0.4 inches (5 and 10 mm) in coastal Maine (Stickney 1964b). Growth in winter is slowed by a decrease in food supply as well as lower temperatures. In Massachusetts, natural mortality rates for dense populations after settlement are estimated to be 70 to 80% per year (TRIGOM 1974).

The burrowed clam obtains its food and oxygen by flushing water through siphons, which are extended above the sediment surface. This action also rids the clam of body wastes. The animal may also adjust its siphon and take in bottom sediments for food, thereby feeding for longer than the period when it is covered with water.

Habitat Preferences

Clams of commercial size are most abundant in the lower one-third of the intertidal zone; however, they are less abundant at the mean low water line (personal communication from W. R. Welch, Maine Department of Marine Resources, Augusta, ME; November, 1979). Optimal growth rates of soft-shell clams in coastal Maine occur in salinities of 15 to 32 ppt.

Pelagic larvae live in the water column of the estuarine and nearshore marine systems. Juveniles live in small patches of sediment found in almost every type of coastal aquatic habitat, whereas most adults are found in intertidal unconsolidated sediments. Adults have been found to live subtidally in upper reaches of estuaries, where temperature and salinity regimes may be unfavorable to their predators (Larsen and Doggett 1978b). Most of the commercial production comes from intertidal mud and sand flats. Adult clams are present in low abundances in dense clay which is found under the silt-clay surface of most mud flats, in sediment pockets on rocky shores, and among the roots of marsh grasses (*Spartina alterniflora*) in emergent wetlands. It is more difficult for predators to attack clams in these areas (TRIGOM 1974) and therefore, these clam populations are potentially a source of larvae that may replenish the flats.

Factors of Abundance

A number of natural factors contribute to fluctuations in soft-shell clam abundance. Among natural factors, predation is the most readily recognized. Diving ducks, bottom feeding fish, horseshoe crabs, boring gastropods, particularly the moon snail (Polinices duplicata), and crabs (especially the green crab) are known to feed heavily on soft-shell clams.

Another factor affecting abundance is high water temperatures that tend to increase the abundance of the predatory green crab. For example, populations of soft-shell clams were low from the late 1940s to the mid-1950s, and during the mid-1970s, when water temperatures were highest and green crabs most abundant (personal communication from W. R. Welch, Maine Department of Marine Resources, Augusta, ME; November, 1977). Boring gastropods are suspected to have increased mortality (based on bore holes in shells of dead clams) among 3 to 5 year old clams in Washington County (personal communication from J. A. Commito, University of Maine, Machais, ME; April, 1979).

Other factors that may affect soft-shell clam abundance are competition for space from blue mussels and possibly the gem clam. Aggregations of mussels that form reefs over clam populations on sand and mud flats may increase clam mortality (Newcome 1935). Gem clams are not often found in abundance with soft-shell clams (Bradley and Cooke 1959; Sanders et al. 1962; and Larsen and Doggett 1978a). Large numbers of gem clams may interfere with the settlement of clam larvae in some locations.

Shifting sediments, salinity extremes (<15 ppt or >32 ppt), and temperature extremes (<17°C or >23°C; 63°F or 73°F) also affect larvae adversely (Stickney 1964a).

Human Impacts

Potential dangers to clam populations in coastal Maine are destruction of habitat and excessive commercial removal. Excessive exploitation apparently is a greater threat to the clam industry than habitat destruction. According to scientists at the Maine Department of Marine Resources, clam populations are severely depleted and they expect that the record high harvests of 1976 and 1977 will probably not reoccur (personal communication from W. R. Welch, Maine Department of Marine Resources, Augusta, ME; November, 1977).

Other factors potentially affecting clam abundance and survival are oil spills, channel dredging, shoreline construction, and the discharge of contaminants. However, little evidence of the effect of these factors on clams is available. The practice of digging clams with a clam hoe can increase mortality rates in clams through breakage of shells and burying of resident clams (Dow and Wallace 1961).

Importance to Humanity

The soft-shell clam strongly supports the commercial and sport-food fisheries of coastal Maine. The commercial industry began in the mid-19th century as a bait fishery for cod trawlers on the Grand Banks. From 1900 to the mid-1940s the clams usually were packed and sold in cans. Currently, fresh or frozen clams dominate the market (Hanks 1963).

The commercial catch has fluctuated greatly in the last 25 years. Highest catches occurred in 1950, 1976, and 1977, when about 7 million pounds were landed (for 1968 to 1978 catch statistics and values see figure 12-1). The catch was under 2 million pounds in 1960. Annual and seasonal fluctuations in commercial demand and clam abundance may limit the expansion of the soft-shell clam industry in Maine. In 1976 Maine supplied 70% of the total U.S. catch but that figure is expected to decrease in the future, because of the increased harvest in Maryland and the general increase in development of other shellfish products.

Although "red tide" (paralytic shellfish poisoning) occurs in the coastal waters of Maine it apparently has little effect on the distribution or abundance of the soft-shell clam, but clams in the infected area may become unfit for human consumption (see "Red Tide," this chapter) and sufficient quantities of toxins may be lethal. In recent years clam harvesting has been banned temporarily in infected areas.

Management

The State of Maine's management of clam resources is based largely on an aggregate of town management plans (personal communication from P. L. Goggins, Maine Department of Marine Resources, Augusta, ME; April, 1978). The state legislature allows towns which have appropriated funds for shellfish management to restrict clam digging to specific flats within their municipal jurisdictions. Forty-seven out of the 102 coastal towns have clam ordinances, and this number includes a relatively high percentage of towns having substantial clam resources (personal communication from P. L. Goggins, Maine Department of Marine Resources, Augusta, ME; April, 1978).

Clam ordinances vary considerably among towns. Conservation measures include the rotation of flats (i.e., digging for clams is prohibited periodically by year on certain flats) to maintain quantities of clams, restriction of nonresident (town) licenses, and regulation of the time of harvest.

The State of Maine requires license fees from individuals landing more than 1/2 bushel of clams at one time and it restricts methods of harvest, such as limiting use of hydraulic dredges to some areas. Hydraulic dredges, which are much more efficient than digging by hand, could, if used extensively, cause rapid depletion of stocks in Maine and excessively disturb bottom organisms and sediments. On the other hand, because dredging in Maine is restricted by law to specific areas along the coast, large scale commercial dredging is not likely (Mathieson and De Rocher 1974). The State may also prohibit clam digging in areas where coliform bacteria counts are high or where red tide and industrial pollution are a threat.

Attempts by the State to place a size limit on clams was found to have no effect on clam populations (Dow and Wallace 1961) and currently no limit is in effect. The market demand for clams smaller than 2 inches is low.

To protect soft-shell clam beds from green crab predation, experimental fences have been used to exclude crabs from beds. Although this method appears to be effective, it is currently cost prohibitive.

Some towns in Maine transplant clams from flats which have high concentrations of juvenile clams to flats which have low concentrations. A potential problem in this practice is that if the cyst form of the "red tide" organism has been ingested by transplanted clams, it will be spread to new areas.

Figure 12-1. Pound (x 10^5, solid line) and dollar values (x 10^5, dotted line) of clam landings for coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

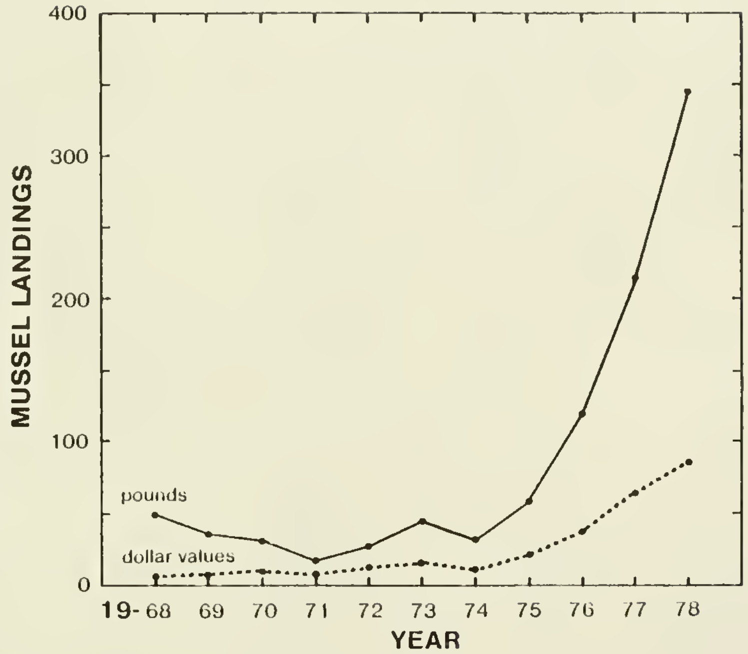

Figure 12-2. Pound (x 10^4, solid line) and dollar values (x 10^4, dotted line) of mussel landings for coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

In principle, the management of clams could be based upon optimum yields. Conceivably, the leasing of clam areas by competitive bidding, a practice common in Maryland, could motivate long term lessees to manage for optimum yields in Maine.

BLUE MUSSEL (*Mytilus edulis*)

The blue mussel is a bivalve that attaches by its byssal threads to hard substrates, and lives in the intertidal and subtidal zones of the marine and estuarine systems. They can endure extensive variations in salinity, temperature, and dissolved oxygen concentrations.

Blue mussels have been cultured and harvested in western France and Spain for hundreds of years. Although they have substantial commercial potential, blue mussels have not been harvested as extensively in the United States. Recently, the demand for mussels as fresh food has increased in the U.S. For a detailed and comprehensive coverage of the mussel industry, see Lutz (1976).

Distribution and Abundance

In the western Atlantic the range of this species extends from the Arctic to South Carolina (Abbott 1974). Blue mussels are also abundant on the West Coast of the U.S. Commercial harvest occurs principally in Maine, Massachusetts, Rhode Island, and Long Island, NY. Greatest abundances in Maine (based on a survey of commercial-sized mussels between the Damariscotta estuary and Jonesport; MARITEC 1978) occur in Frenchman Bay (region 3), and the Blue Hill Bay - Deer Isle area (region 5). Mussel beds known to be commercially harvested in Maine are depicted in atlas map 4.

Life History

Completion of the life cycle requires about one year. In the characterization area, spawning occurs at low levels throughout the year, but the principal spawning period is between mid-May and mid-June, with another spawning possibly occurring in the fall (personal communication from L. S. Incze, University of Maine, Orono, ME; June, 1978).

Between 5 and 12 million eggs may be produced by a single female mussel in a year (Field 1922). Sexes are separate and gametes are shed into the water where fertilization occurs. Depending on environmental conditions, the larvae are pelagic for approximately 19 days (personal communication from L. S. Incze, University of Maine, Orono, ME; November, 1977). In the pelagic environment, the larvae are subjected to biotic and abiotic stresses. Mortality at this stage is believed to be very high.

The larvae first settle on flexible substrate such as algae, hydroids, or byssal threads but they may detach and resettle one or more times until they find an appropriate substratum. The larva may delay metamorphosis for some time if the appropriate substratum is not available; however, after about 8 weeks or when a length of 0.06 to 0.4 inches (1.5 to 10 mm) is reached the larva will settle wherever it is at that time (Mason 1972). Upon metamorphosis the mussel is considered a juvenile.

In the first year juvenile mussels have been observed to reach a length of 0.8 to 1.6 inches (20 to 40 mm) in Massachusetts (Field 1922). In Denmark, Rasmussen (1973) found growth of 1 inch (25 mm) in the first 4 months. In the Damariscotta estuary, average growth of cultivated mussels for 1 year is approximately 2 inches (50 mm; Incze et al. 1978); however, MARITEC (1978) found natural populations of mussels in Maine to be 2.4 inches (60 mm) at 8.2 years and 2.8 inches (70 mm) at 9.5 years.

The diet of mussels consists of phytoplankton and detritus filtered from the surrounding water (TRIGOM 1974).

Habitat Preferences

West of Schoodic Point (regions 1 to 5), mussels of commercial size are most abundant approximately 3.2 feet (1 m) above and below mean low water level, whereas most beds in the Jonesport area (region 6) are above mean low water level (MARITEC 1978). Subtidal beds are located almost exclusively in areas with good currents, especially around offshore islands and in the mouths of estuaries. These beds are far less numerous than intertidal beds.

Pelagic larvae live in the water columns of estuarine and marine systems. Optimal conditions include an adequate food supply, salinities between 15 and 40 ppt and temperatures ranging from 41 to 68°F (5 to 20° C).

Juvenile and adult mussels are found in every type of intertidal habitat present in coastal Maine. Juveniles are extremely abundant on rocky shores, while both adults and juveniles are plentiful in low intertidal areas on gravel beaches, and as part of fouling communities on pilings and on flats, particularly mud flats. Mussels are especially abundant in areas of high water flow such as tidal falls. The commercially harvested beds are principally found on intertidal mud flats and unconsolidated sediments in shallow subtidal waters.

Factors of Abundance

Mussel abundance in coastal Maine is determined by a number of natural limiting factors which include predation, competition, and climatic factors. Common predators include sea ducks, gulls, whelks, starfish, crabs, and bottom feeding fish. The dog whelk (*Thais lapillus*), by preying on juveniles, may limit mussel abundance on rocky shores, particularly in the more protected areas (Menge 1976). Eider ducks have been reported to eat approximately 425 g (1 pt) of mussels in one day (Field 1922). Up to 80% of the stomach contents of these ducks in the summer is comprised of juvenile mussels (Graham 1975).

The most significant competition among blue mussels is for food and space between individuals. As younger mussels settle and accumulate on established beds, older ones are buried and may be smothered. Theisen (1972) found that mussels regularly clean their shell surfaces with their foot, and he suggested that this cleaning action wards off other mussels trying to settle on them. Mussels may also move within the bed, out from under other mussels to a more exposed position.

Waves generated during northeast storms, which occur in Maine in the fall, winter, and spring, cause high mortality rates in mussels. Some storms destroy entire mussel mats in the intertidal zone. Consequently, on exposed rocky shores, the majority of blue mussels are juveniles.

Human Impacts

Evidence indicates that mussel populations may be depleted if harvesting continues at present or greater levels (Dow and Wallace 1954; and MARITEC 1978). Stocks of mussels are already depleted between the Damariscotta estuary (region 3) and Rockland (region 4) according to MARITEC's survey (1978). Overharvesting and natural factors may have contributed to the decline in abundance.

Other human impacts on mussels include habitat destruction, oil spills, dredging, and discharge of contaminants. Evidence of the effect of these factors on populations of mussels in coastal Maine is lacking.

Importance to Humanity

The blue mussel once supported a part-time shell fishery in Maine but during World War II the need for substitute sources of protein prompted an increase in fishing effort. The harvest increased during the war and peaked at over 2.5 million pounds in 1944 (Maine Landings 1944). In 1947 the harvest declined to approximately 40,000 lb (Maine Landings 1947). Dow and Wallace (1954) feel that the decline was not only due to a decline in demand for mussels but also due to the fact that readily available natural stocks of mussels were no longer available.

The landings of blue mussels have steadily risen since 1974 to almost 3.5 million pounds in 1978 (see figure 12-2). This increase is attributed to growth in demand for inexpensive protein.

Mussels infected by "red tide" are unfit for human consumption and in recent years harvesting of mussels in infected areas has been temporarily banned. Little effect of red tide on the distribution and abundance of mussels is apparent; however, high levels of toxin can cause mortalities.

A factor that limits commercial harvest of mussels is the presence of pearls in the meat of the mussel. Mussels containing pearls are usually unacceptable commercially. Evidence exists that pearls are the result of infestation by a trematode (Gymnophallus; Lutz 1976), of which the life history is unknown. Evidence also exists that the adult host is a sea duck (a scoter or an eider), the blue mussel being the intermediate host (Stunkard and Uzmann 1958). Whether natural mechanisms of pearl formation exist is not known (Lutz 1976).

Management

Management of mussel resources in the State of Maine is similar to that of clam resources. Towns which have appropriated funds for shellfish management are allowed by the State to regulate harvesting activities within their jurisdictions. Most town ordinances, however, pertain to clams and do not regulate mussels specifically.

License fees are required from individuals landing more than 1/2 bushel of mussels at one time. The Maine Department of Marine Resources regulates aquacultural operations. Regulations vary with location, but leasing of the area and/or attaining shore access is usually required. The state may close mussel harvesting in areas where coliform bacteria counts are high or where "red tide" and industrial pollution occur.

The New England Fisheries Development Program, of the National Marine Fisheries Service, is studying methods of sustaining the mussel fishery. Problems include potential overharvesting (Lutz 1976) and the harvesting of poor quality mussels (those that are small in size or contain pearls). If harvests continue to be low in quality, commercial demand is likely to decline. NMFS conducted a survey through MARITEC (1978) of mussel beds between the Damariscotta estuary and Jonesport and made harvest and management recommendations.

Mussel culture is being explored as a means of meeting market demand (Lutz 1974; and Lutz and Porter 1977). Culturing experiments and a commercial culturing operation have been successful in Maine, but financial gains have been inadequate. However, mechanization of the currently labor-intensive culturing process combined with increased demand for mussels could change this situation.

For culturing, individuals from natural populations at one location are sometimes needed to supplement natural juvenile populations in other locations. This practice potentially impinges on natural populations because it strips juvenile mussels and associated animals (amphipods and oligochaetes) from exposed rocky shores. Transplanting mussels carries the same risks as transplanting clams, i.e., the potential for spreading "red tide" via ingested cysts.

SEA SCALLOP (Placopecten magellanicus)

The sea scallop is a bivalve which lives on the sediment of subtidal areas. The large muscle that holds the two shells of the scallop together is harvested commercially for fresh food. Scallops are the most commercially valuable (price/lb) shellfish species harvested in Maine.

Distribution and Abundance

Scallops are found from Newfoundland to North Carolina. Although they can swim freely in the water, scallops do not migrate far. They often occur in dense but scattered populations or beds.

Commercial harvest occurs in Newfoundland, Prince Edward Island, Bay of Fundy (Digby and Grand Manan), embayments and mouths of estuaries on the coast of Maine, Stellwagen Bank in the Gulf of Maine, Cape Cod Bay, Georges Bank, and near Hudson, Baltimore and Norfolk Canyons at the edge of the continental shelf (Altobello et al. 1976). The largest fishery is on Georges Bank where 65% of the total catch of the U.S. and Canada from 1940 to 1975 was taken (personal communication from J. A. Posgay, National Marine Fisheries Service, Woods Hole, MA; November, 1977).

In Maine, the most important coastal scallop fishing areas are: Penobscot Bay to Mt. Desert Island, the Harrington and Pleasant Rivers, and the Jonesport area (Baird 1967). Lesser areas are Casco Bay, and the Piscataqua (Maine-New

Hampshire border) and Damariscotta Rivers. At one time the Sheepscot estuary supported scallops in abundance but they have largely disappeared. There is no proven explanation for the disappearance. Commercially valuable scallop beds are illustrated in atlas map 4.

Life History

Scallops in Maine waters are reported by Baird (1967) to reach sexual maturity in the third or fourth year of life or at the size of 2.2 to 2.9 inches (56 to 74 mm). Spawning occurs from July to October, with peaks in late August in eastern Maine (region 6; Bourne 1964) and in September in Penobscot Bay (region 4; Baird 1953). Spawning is believed to be triggered by a slight change in temperature; however, some investigators believe a rise in temperature is necessary (Culliney 1974) whereas others claim a drop in temperature initiates spawning (Altobello et al. 1976). According to Culliney (1974) optimal temperatures for successful spawning of natural populations is about 46 to 52°F (8 to 11°C).

No information is available on the number of eggs released per individual; however, it can be assumed that numbers would be several million, as is typical of large molluscs (TRIGOM 1974). Sexes are separate, and gametes are released into the surrounding water where fertilization occurs. The larvae are pelagic in laboratory conditions from 23 to 35 days (Culliney 1974). The length of this stage in natural conditions is unknown, since the planktonic larvae of this species of scallop have never been positively identified in the ocean.

After approximately a month the larvae undergo metamorphosis and develop eye spots, a foot, and byssus (Culliney 1974). Settling response, according to Culliney (1974), is related to contact with a solid body and is not highly specific as to type. Natural populations of juvenile scallops have been found attached by their byssus to the branches of a bryozoan (Baird 1953), to a hydrozoan, to amphipod tubes, and to grains of sand (Larsen and Lee 1978).

Natural mortality of juvenile scallops is high according to surveys in February and May on Georges Bank, which indicated a sharp drop in abundance of live scallops (Larsen and Lee 1978).

Baird (1967) reports that scallops grow to 0.08 inch (2 mm) in their first winter and Larsen and Lee (1978) report a growth of 0.05 inch (1.3 mm) in the 5 months after settlement on Georges Bank. These growth rates are slower than those observed on and around navigational buoys in the Nantucket Shoals area, 0.08 to 0.5 inch (2 to 14 mm). The adult size generally ranges from 2 to 4.9 inches (50 to 125 mm; Baird 1967).

The scallop feeds on phytoplankton and suspended detritus, which it filters through its gills.

Habitat Preferences

In Maine, scallops of commercial size are most abundant in saline waters (>30 ppt) at depths of approximately 20 m (66 feet; personal communication from D. F. Schick, Maine Department of Marine Resources, Augusta, ME; April, 1978). In the southern part of the range, i.e., Long Island to North Carolina, the commercial fishery is at depths >50 m (>165 ft). In colder waters of Maine scallops are sometimes found close to the low water mark.

Pelagic larvae live in the water column of the marine and high salinity areas (>20 ppt) of the estuarine system. In laboratory experiments temperatures above 66°F (19°C) over an extended period of time were fatal to larvae.

The juvenile and adult scallops live in subtidal marine waters and in areas of comparatively high salinity (approximately 20 to 25 ppt) in estuarine systems. Estuarine populations are generally found in deep channels where temperatures and salinity are least variable (Welch 1950). They live on unconsolidated sediments, usually sand or gravel, and to a lesser degree on rocky bottoms.

Factors of Abundance

Temperature is the most critical natural factor limiting the distribution and abundance of the sea scallop. High summer water temperatures of 68 to 74 °F (20 to 23.5 °C) limit the distribution of adult scallops to deeper waters in the southern region of the species' range (Long Island and further south; Bourne 1964). The maximum temperature for larvae is about 19°C (66 °F; Culliney 1974). The water temperature must reach a minimum level of 46 °F (8° C; Posgay and Norman 1958), 49°F (9.5°C; Dickie 1955) or 51°F (14°C; Culliney 1974) for spawning to occur. In the northern part of their range, only the shallower waters of New England and the Maritime Provinces of Canada are warm enough to meet this minimum temperature requirement.

Scallops have a limited ability to withstand reduced salinities; hence, they are not found in areas of low salinity (<20 ppt) in estuaries.

Sporadic large-scale mortality has been observed in beds of sea scallops in Maine (as large fluctuations in landings corroborate; see figure 12-3) and elsewhere, but the cause has not been determined. Medcof and Bourne (1962) suggest that sudden, extreme change in temperature may contribute significantly to natural mortality. They estimate the rate of natural mortality in scallops over 3 years old is 10% of the population, based on numbers of living and newly-dead individuals in dredge catches. Merrill and Posgay (1964) derived the same rate for offshore populations on Georges Bank.

Scallops can live at least 8 years (Baird 1967). Predators include Atlantic cod, American plaice, Atlantic wolffish, the northern starfish (*Asterias vulgaris*), and the common sun-star (*Crossaster papposus*). The extent to which predators affect populations of scallops is unknown.

Human Impacts

Fishing indirectly may lead to high mortality in scallop populations through disrupting the bottom sediment by dragging, and through exposing and damaging discarded small scallops. Medcof and Bourne (1962) estimate that fishing mortality may reach an annual rate of 10% in the inshore populations in Nova Scotia.

Other factors potentially affecting scallop distribution and abundance are oil spills, dredging, spoil disposal, and discharge of heated effluents or contaminants.

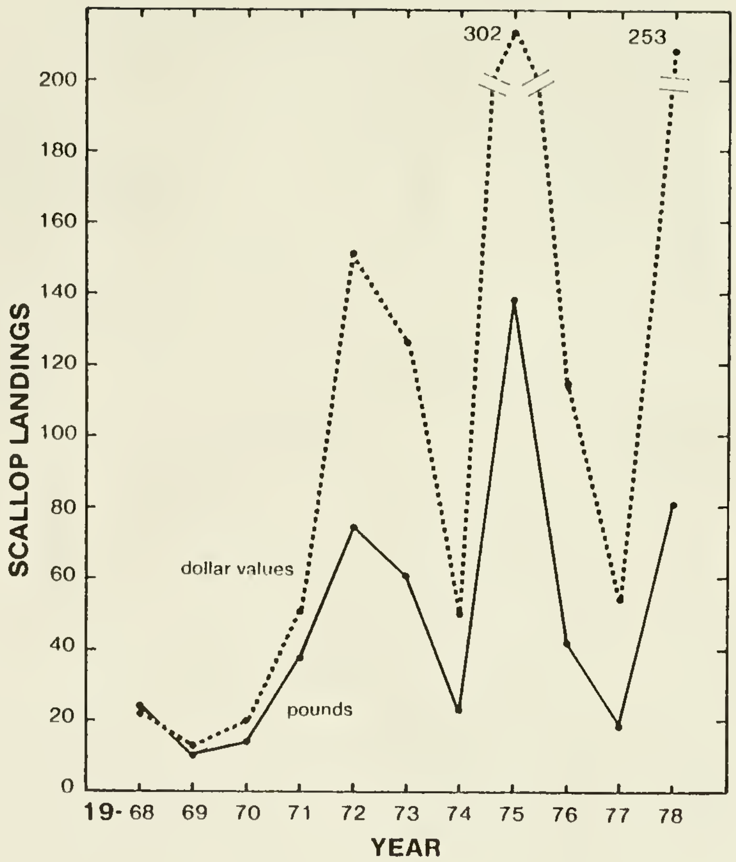

Figure 12-3. Pounds (x 10^4, solid line) and dollar values (x 10^4, dotted line) of scallops landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

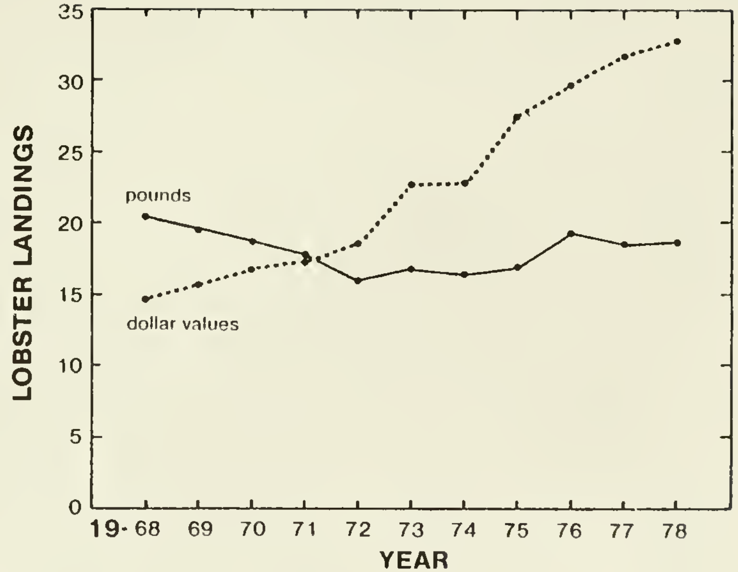

Figure 12-4. Pounds (x 10^6, solid line) and dollar values (x 10^6, dotted line) of lobsters landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

Importance to Humanity

The sea scallop has been used for food in Maine since colonial times, although a commercial fishery did not develop until the latter part of the 19th century. In 1910 a catch of over 2 million pounds of scallops was recorded for nearshore waters of Maine.

Catch statistics have varied considerably over the last 10 years (see figure 12-3). Variations may be the result of incomplete or inconsistent reporting as well as changes in abundance.

The 1978 peak may be due to more extensive fishing for scallops in offshore waters. As of November 1978, at least 30% of the catch (Maine Landings 1978) came from the offshore fishery. In previous years the catch during the months when the inshore fishery is closed amounted to <1% of the total catch for the year.

The inshore scallop fishery in Maine is seasonal by law (see below). Most scallop fishermen harvest either lobsters, mussels, or fish during the other months of the year.

Management

Maine's inshore sea scallop fishery is subject to several state regulations. Since 1947 the scallop fishing season has been closed from 16 April to 31 October. There are no closed seasons offshore of the headlands and principal islands in Penobscot Bay (see Maine Marine Resources Laws and Regulations, 1979, for exact locations). The purpose of the closed-season regulation is to allow scallop beds disrupted by fishing to reaggregate. The effect of the closed season on inshore beds is unknown.

A license is required for harvest of over 2 bu of shelled scallops or 4 qt of shucked scallops in any one day. Minimum legal size is 3 inches (76 mm) in the longest diameter. If more than 10% of any catch consists of undersized scallops, the fisherman is liable to a fine. The minimum-size limit is enforced to allow scallops to reproduce at least once before being harvested.

AMERICAN LOBSTER (*Homarus americanus*)

The American lobster is a decapod (i.e., ten-legged) crustacean that lives on subtidal bottoms. It is an omnivorous scavenger that feeds primarily at night and finds shelter in burrows or crevices during the day. Lobstering supports the largest commercial shellfish industry in Maine.

Distribution and Abundance

Lobsters are found from Labrador to North Carolina, from mean low water level to depths over 2300 feet (700 m). Major commercial fishing occurs in coastal waters and along the edge of the continental shelf, particularly in the submarine canyons (e.g., Hudson Canyon).

Commercial fishing in the characterization area is principally in coastal bays around nearshore islands and in high salinity waters (>20 ppt) of estuaries.

Life History

The reproductive cycle of the American lobster is typical of crustaceans. The sexes are separate, and copulation occurs immediately after the female molts, usually in early summer or fall. The female stores the sperm in her body from 2 weeks to 15 months before the fertilized eggs are extruded (Cobb 1976). Thomas (1973) estimates that eggs are released by the female between May and July in coastal Maine lobster populations. The age and size of a female determines the number of eggs produced. Approximately 10,000 eggs are produced by a 1 lb lobster, and 130,000 by an 18 lb lobster (Perkins 1971).

The fertilized eggs are held on pleopods (appendages) on the female's underside until the following summer, when they hatch. Under laboratory conditions the mortality rate of the eggs until hatching is about 35% (Perkins 1971). The length of the hatching period depends on temperature. In the laboratory at optimum temperature of 68°F (20°C), hatching will occur in 16 weeks; 39 weeks are required at 50°F (10°C; Hughes and Matthiesen 1962; and Cobb 1976). Hatching period and mortality rate of eggs under natural conditions are unknown.

Immediately after hatching, larvae assume a planktonic (suspended in the water column) existence in Maine waters that lasts from 5 to 6 weeks. They are subjected to the biotic and abiotic stresses of the water column environment. As in all arthropods, which have hard outer shells, growth in American lobsters is achieved through molting. Larval lobsters molt four times before settling to the bottom.

On assuming a benthic existence, lobsters are considered juveniles. In Maine, approximately 10 molts (4 as larvae) occur in the first year, after which juveniles molt two or three times per year. After the fifth year, molting is annual (usually mid-summer to early fall) but it may be biannual for adult females who are carrying eggs. In mature lobsters each molt results in increases in length of up to 14% (Cobb 1976).

Warm temperatures increase the growth rate of lobsters. The fastest-growing individuals may reach sexual maturity in 4 years, but most do not mature until they are 5 to 7 years old. Krouse (1972) found that in Maine male lobsters mature at smaller sizes than females. Fifty percent of the males may be mature at 1.7 inches (44 mm) carapace length, whereas few females mature until they have exceeded the minimum length legal for harvest, 3.1 inches (81 mm). Thomas (1973) estimates that in Maine females mature at a size between 3.5 and 3.9 inches (90 and 100 mm). Lobsters can live for over 20 years.

The diet of lobster is flexible and includes crustaceans (e.g., crabs) molluscs (e.g., small clams), echinoderms, algae, and hydroids. It has been estimated by Miller and coworkers (1971) that the American lobster in Nova Scotia consumed approximately 10% of the secondary production in the community studied.

Habitat Preferences

Lobsters are found principally in the marine system and high salinity areas (>20 ppt) of the estuarine system.

Larvae live in the water column and juvenile and adult lobsters in the subtidal zone on unconsolidated and rocky bottoms. Adults and juveniles are most abundant on bottoms that provide shelter in the form of rock crevices (rock bottom), plant life (aquatic beds), or the potential to dig a burrow (unconsolidated bottoms). These shelters partially protect the lobster from predation and from aggression from other lobsters.

Factors of Abundance

Natural factors that contribute to fluctuations in lobster populations include predation, disease, and environmental factors. Highest natural mortality rates occur among larvae and juveniles. Larvae are preyed upon by surface-feeding fish such as lumpfish, while juveniles are preyed upon by small bottom-feeding fish, such as the cunner. Larger bottom-feeding fish (such as cod, skates, and sharks) prey on adult lobsters.

Salinity limits the distribution of lobsters in the characterization area. The lowest salinity tolerance in the laboratory was 13.8 ppt for larvae and 8 ppt for juveniles and adults (Cobb 1976). Under natural conditions, lobsters, particularly larvae, probably avoid areas where the salinity is lower than approximately 20 ppt.

Lobsters may limit their own numbers, also, but the extent of this is unknown. Lobsters are very territorial, aggressive, and cannibalistic. Mortality due to aggressive behavior is probably higher on bottoms that do not have shelter, i.e., crevices in rocks or sediments where lobsters can burrow.

The species is susceptible to several fatal diseases at various stages in its life cycle. In the larval stage, *Leucothrix mucor* (a filamentous bacteria) collects in the gill membranes and suffocates the organism, and a fungus, *Lagendinium* sp., breaks down larval tissues. Another fungus, *Haliphthoros milfordensis*, infects juveniles and breaks down their shells, exposing more vulnerable inner layers. The most common disease in adults is gaffkemia, or "red tail," which is a bacterial (*Aerococcus viridians homari*) infection of the blood. The infection begins in an open wound usually inflicted by fishermen in the process of plugging the claws (immobilizing the claw with a wooden plug to stop cannibalism) or in notching berried (egg-carrying) females. These diseases may occur more frequently in lobsters that are kept in enclosed areas, such as containers (for aquaculture) or lobster pounds. Crowding of lobsters and unsanitary conditions increase the incidence and magnitude of disease.

The highest natural mortality rate in lobsters occurs after molting, before the shell hardens. Besides being vulnerable to predation, lobsters are also subject to aggressive attacks, usually for territorial reasons, by other lobsters that are not in the process of molting and have hard shells. Also, lobsters in the molting stage have been found to be less resistant to high temperatures and low salt or oxygen levels (McLease 1956).

Human Impacts

Commercial harvesting is the principal limiting factor in adult populations of lobsters. The fishing mortality rate of legal-sized lobsters in Maine may be as high as 90% (Thomas 1977). In fact, results of a tagging study (Krouse

1977) show that 65% and 75% out of 3000 tagged lobsters were captured within 4 months and 1 year respectively. Recently molted animals actively seek food and may be trapped by fishermen more easily than hard-shelled lobsters which may confine their feeding activity to a smaller territory (Thomas 1973).

Perturbations such as oil spills, dredging, spoil disposal, and discharge of contaminants could potentially affect lobster populations, but the effects of these factors on lobster distribution and abundance in Maine are unknown.

Importance to Humanity

The lobster industry is the largest commercial shellfish industry in Maine. The landings and dollar value of the lobster fishery are given for the last 10 years in figure 12-4.

The fishery began in the early 19th century when fishermen from other States came to Casco Bay. Local fishermen began to fish for lobster soon after and the fishery was established in Eastport by the middle of the century.

In the early 1950s significant changes took place in the gear used in lobstering, especially the introduction of the hydraulic haul. With the new haul and bigger, more powerful boats each fisherman could manage a greater number of traps; thus the lobster catch increased (figure 12-5). Since that time fishing intensity (in terms of numbers of traps) has increased while catch has decreased (figure 12-5).

Management

Many types of restrictive regulations apply to the lobster fishery. They include: licensing; use of conventional traps with escape vents; maximum and minimum-size restrictions (3.1 to 5.5 inches, or 81 to 127 mm, carapace length); prohibition of removing berried lobsters, scrubbing eggs off, or removing those marked with a notch (marked by the MDMR to identify egg carrying females) on the second flipper from the right; trap limitations on a single line in some areas; and limitation of fishing hours in the summer (1 June to 31 October). Lobster fishermen of 2 offshore islands (Monhegan and Criehaven) may petition the Commissioner of Marine Resources to control their fishing seasons.

Thomas (1973) and Dow and coworkers (1975) submitted two lobster-management recommendations to the State legislative committees as a result of their research. The first was to raise the minimum-size limit from 3.1 to 3.5 inches (81 to 89 mm). It is estimated that 80% of the legal-size lobsters harvested in Maine are between 3.1 and 3.6 inches (81 and 92 mm; Thomas 1973). This means that lobsters are caught as fast as they reach legal size and that most females do not spawn once before they are harvested. This recommendation has not yet been implemented. The second recommendation (which has been implemented) was to increase the space in the sides of traps, that allows small lobsters to escape before traps are hauled. The increase to 1.75 inches (44.5 mm) would reduce injury and loss of claws.

Attempts have been made recently in Maine to explore the potential of the American lobster for aquaculture. If lobsters could be raised successfully it might be possible to supplement natural populations as well as support

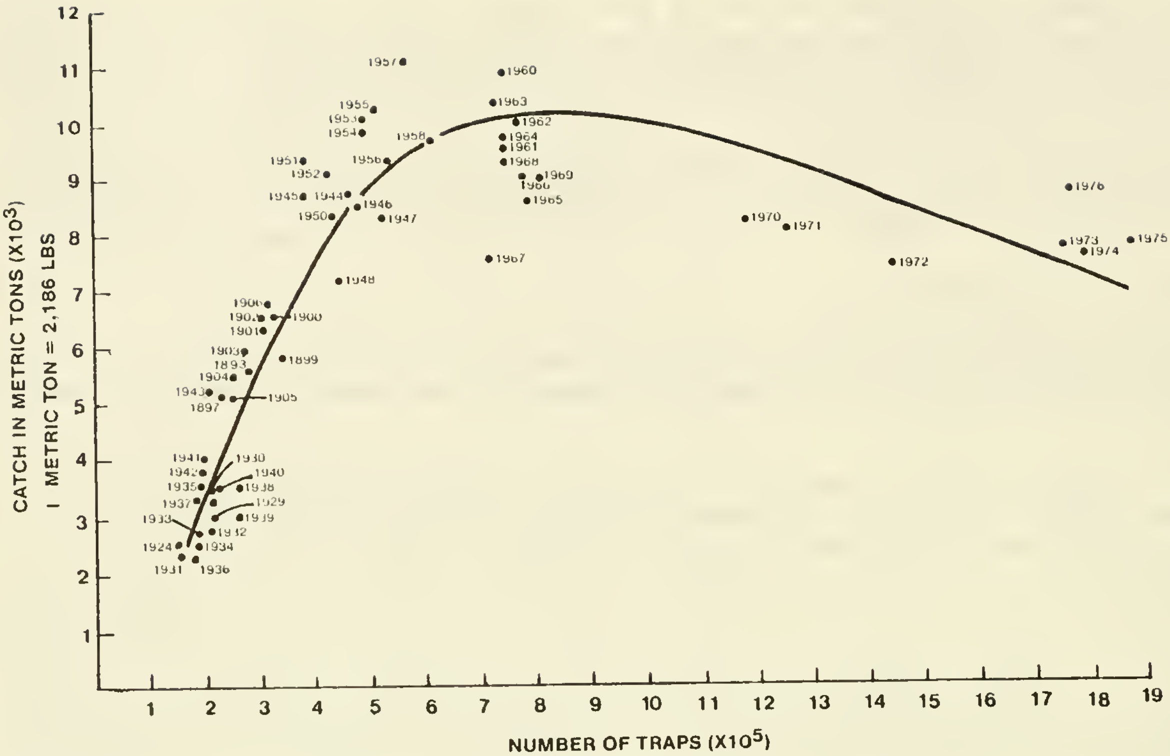

Figure 12-5. Correlation of lobster catch (thousands of metric tons) and number of traps fished (hundred thousands) in Maine for 1897 to 1976 (Maine Department of Marine Resources 1977).

commercial aquaculture. Although this species has been raised to adulthood in the laboratory, large-scale aquaculture is impractical. The aggressiveness of the species requires that each lobster be raised in an individual container, feeding is expensive, and lobsters are more susceptible to disease in culture than in the natural environment.

ROCK CRAB (<u>Cancer irroratus</u>) and JONAH CRAB (<u>Cancer borealis</u>)

A small commercial crab fishery in Maine is supported by the rock crab and the Jonah crab. Most Maine fishermen commonly refer to <u>C. borealis</u> as the rock crab and to <u>C. irroratus</u> as the sand or mud crab. Both species are brachyurans, or true crabs, and may reach a size of 2.3 inches (60 mm) at maturity (Krouse 1976). Females tend to be smaller than males. Although neither species has been studied extensively, more information is available on the life cycle and habits of the rock crab than of the Jonah crab.

<u>Distribution and Abundance</u>

These 2 species of crab range from Labrador to Florida (TRIGOM 1974). The rock crab is the more abundant of the two in the intertidal zone of coastal Maine and may be found from low water to 1980 feet (600 m). The Jonah crab may be found from the shallow subtidal zone to a depth of 2640 feet (800 m) (Gosner 1971). The major areas of harvest of crabs in coastal Maine are in

Casco Bay, the Sheepscot and Damariscotta estuaries, upper Penobscot Bay, and Blue Hill Bay.

Life History

The sexes of rock and Jonah crabs are separate, and in Maine breeding occurs in the fall when females are molting (males molt later, in February or March). Copulation occurs just after the female molts and the several thousand eggs are extruded in late fall or early winter. Fertilized eggs are carried by the female from 6 to 9 months until they hatch. Krouse (1976) estimates that hatching occurs from June to August in the Gulf of Maine and that the larvae are planktonic until August or September (approximately 40 to 60 days).

Krouse (1976) found that young crabs settle in the intertidal zone and remain there until the second year of life, or until they reach a size of 1.9 inches (50 mm). Then, when the temperature begins to drop, they migrate seaward. Growth slows considerably in winter.

Both species are carnivores and feed on polychaetes, sea urchins, mussels, and starfish (Scarratt and Lowe 1972).

Habitat Preferences

For the first 1.5 to 2 months of life, crabs are pelagic and part of the meroplankton (floating eggs and larvae). As such they are subject to heavy predation.

The two species inhabit different bottom types. The Jonah crab is found predominantly in rocky bottoms, where shelter is readily available. The young rock crab, under 1.9 inches (50 mm), settles on rocky bottom or rocky intertidal areas but may later shift to a more open environment, such as unconsolidated bottoms of sand or mud (Stasko 1975; and Scarratt and Lowe 1972). The rock crab is more active than the Jonah crab and burrows quickly in unconsolidated bottoms, or runs, when approached by predators (Jeffries 1966). The Jonah crab, when approached by predators, finds a crevice on a rocky bottom and defends itself with its large claws.

Factors of Abundance

The rock and Jonah crabs have a limited tolerance to extreme environmental fluctuations . Larval mortality is high in salinities under 20 ppt (Sastry 1970). Jeffries (1966) found, using "walking ability" as an indicator of temperature effects on adults of both species, that optimal temperature for the rock crab was 57 to 64°F (14 to 18°C) and for the Jonah crab, 43 to 57°F (6 to 14°C).

Predators on small crabs include various bottom-feeding fish and the American lobster. Mature crabs are sometimes preyed upon by large cod (TRIGOM 1974).

Human Impacts

Studies on Jonah and rock crabs indicate that commercial harvesting is highly selective, favoring larger crabs, generally males. It is believed that crabs are being harvested at close to the optimum capacity to sustain the population (personal communication from J. Cowger, Maine Department of Marine Resources, Augusta, ME; November 1977). The effects of fishing on these crabs are unknown.

Other potential impacts include dredging and spoil disposal, oil spills, and other toxic discharges. The effect of these factors on the Jonah and rock crab populations is unknown.

Importance to Humanity

In the past, harvest of the rock crab and the Jonah crab has been incidental to the lobster fishery in Maine. Lobstermen commonly find crabs, particularly the rock crab, in their traps and usually discard them; however, as prices continue to rise, fishing intensity will increase and more crabs will be kept and sold by lobstermen. Fishermen who fish specifically for crabs use crab pots that lobsters cannot enter.

Although landings of crabs in the last 10 years have been variable (see figure 12-6), the value of the crab fishery in the last few years has increased rapidly. The actual harvest may have been significantly greater than what the data indicate, as many crabbers process the meat at home and sell directly to retailers. Almost the entire crab harvest is sold as fresh, handpicked meat within the State (Fisheries Development Corporation 1977).

Management

Currently, there are no management regulations on crab resources in Maine. Harvest restrictions on the fishery are the same as those on the lobster fishery.

NORTHERN SHRIMP (*Pandalus borealis*)

The northern shrimp is a decapod crustacean that is circumboreal (i.e., found around the world in the boreal zone) in distribution and occurs in both inshore and offshore waters at various stages in its life cycle. The species may reach a size of 6 inches (150 mm) at maturity (TRIGOM 1974) and during its life span usually functions first as a male, for 2.5 to 3.5 years, then as a female.

In the past, the shrimp fishery of Maine has been erratic. It reached a peak in the late 1960s but since then has been declining.

Distribution and Abundance

In New England, the northern shrimp occurs in the Gulf of Maine, especially near Jeffrey's Ledge, southwest of Cashes Ledge, and southeast of Mt. Desert Island, at depths from 30 to 1100 feet (9 to 329 m; Haynes and Wigley 1969).

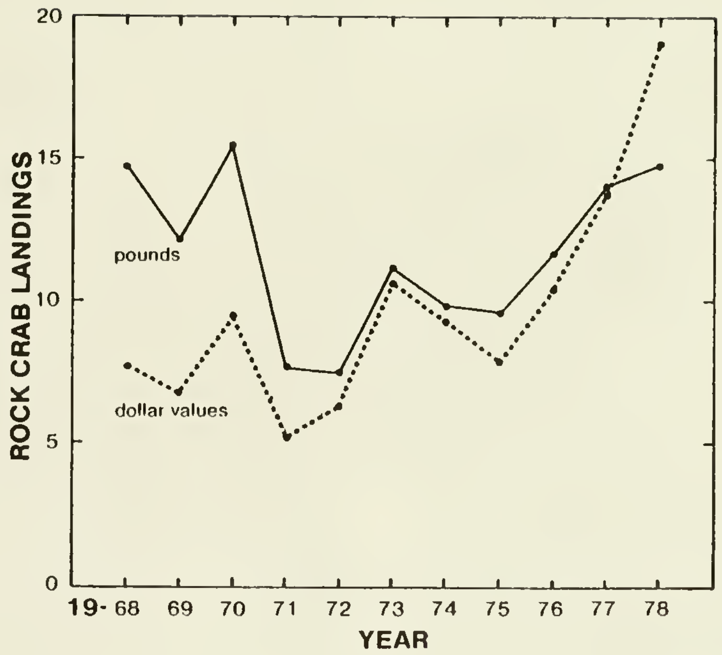

Figure 12-6. Pounds (x 10^5, solid line) and dollar values (x 10^4, dotted line) of rock crab landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

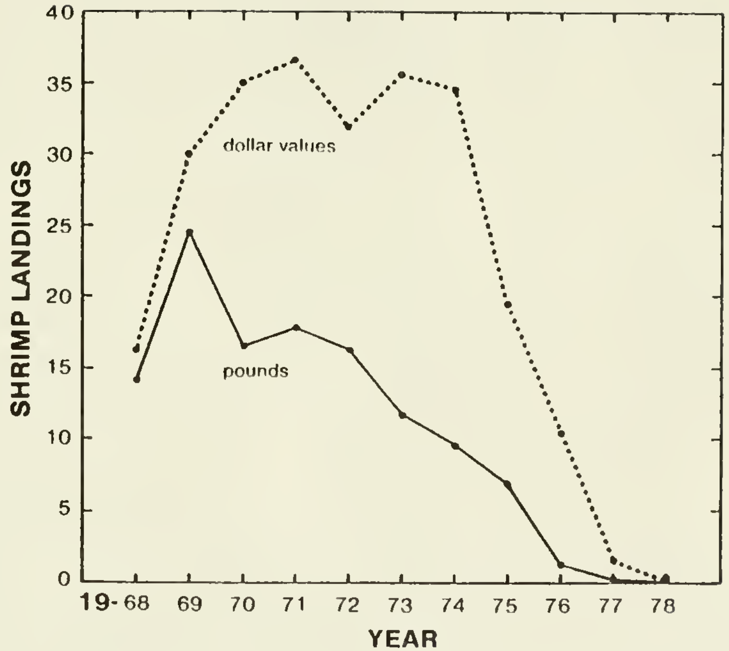

Figure 12-7. Pounds (x 10^6, solid line) and dollar values (x 10^5, dotted line) of shrimp landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

Life History

Between the ages of 1 and 3 years, most individuals of this species are sexually mature males. The transition to the female gender may begin as early as 20 months, although it is more common at 32 months, and by 43 months almost all individuals are functional females (Haynes and Wigley 1969). Some females spawn twice, although most spawn only once in their lifetimes. Estimated normal life span for individuals of this species in the Gulf of Maine is 4 to 5 years (Wigley 1972).

In offshore waters of the Gulf of Maine copulation occurs after females molt (Haynes and Wigley 1969). Eggs (330 to 500) are carried on the female's pleopods (appendages on the underside) through the winter, during which time females migrate inshore. Egg-bearing shrimp may prefer cold water and therefore in the winter move gradually inshore, where the waters are cooling (Stickney and Perkins 1977). The time of hatching depends on water temperatures during the winter in which the eggs are being carried on the female. In warm years hatching may take place as early as February and most hatching is usually completed by April (personal communication from A. P. Stickney, Maine Department of Marine Resources, Augusta, ME; November, 1977). After hatching, larvae are planktonic (suspended in the water column) until they lose their exopods (swimming appendages) after about three months (Stickney and Perkins 1977). Male juveniles remain inshore until their second winter (end of 2nd year) when they begin to migrate offshore. In the fall egg-bearing females (end of 4th year) begin their migration inshore.

The diet of the adult shrimp varies with the season, consisting of a larger proportion of molluscs in the winter and crustaceans in the summer. The shrimp may also eat polychaetes, protozoans, and echinoderms.

Habitat Preferences

The northern shrimp is considered a benthic species, although males and females not carrying eggs may migrate vertically through the water column at night to feed. Shrimp live in the subtidal zone of the marine system, usually on unconsolidated bottoms composed of mud, silt, or sand that are high in carbon and nitrogen content (Bigelow and Schroeder 1939). Larvae live in the water column.

Factors of Abundance

The northern shrimp appears to have well-defined environmental requirements. Salinity tolerance as high as 30 to 35 ppt is suggested by Wigley (1972) and Haynes and Wigley (1969). The temperature tolerance of this species ranges from 28 to 53°F (2 to 11.5°C), although larvae can live in waters as warm as 57°F (14°C; TRIGOM 1974).

There are 2 known parasites of the northern shrimp. One of these affects the eggs of the shrimp and has been tentatively identified as a parasitic dinoflagellate (Stickney 1978). The affected eggs are no longer viable and fecundity is reduced. The other organism is a dinoflagellate of the genus *Gymnodinioides* and infects the gills of adult shrimp (Apollonio and Dunton 1969). It is not known if mortalities from these parasites alter the shrimp population.

Human Impacts

Overharvesting as occurred in the late 1960s was the major limitation on shrimp populations. Initially the catch consisted almost exclusively of egg-bearing females, which are the largest individuals of the species and which inhabit shallower waters. In recent years larger vessels, improvements in fishing gear, and changes in fishing season have increased the proportion of males and transitionals in the catch.

Discharges of oil and other contaminants have the potential to affect shrimp populations. The effect of these factors on shrimp stocks is unknown.

Importance to Humanity

The northern shrimp has supported a commercial fishery in Maine since 1938. In the early years the shrimp were harvested primarily from February to April, and the bulk of the catch was sold frozen (Scattergood 1952).

In the early 1940s several packing plants for shrimp opened, and since then the demand for shrimp has steadily increased. A sharp decline in the fishery occurred in the early 1950s, with no landings at all from 1954 to 1957 (Maine Landings 1954 to 1957). High winter temperatures during 1950 to 1953 are believed to have adversely affected shrimp populations during that time (Apollonio and Dunton 1969).

The harvest began to increase dramatically in the 1960s, and by 1968 the catch was over 12 million pounds (Apollonio and Dunton 1969). However, a decline in catch per unit of fishing effort followed, falling from a peak of over 6000 lb/day fishing in 1969 to less than 2000 lb/day fishing in 1976 (Clark and Anthony 1977). The shrimp catch and dollar value for the last 10 years are illustrated in figure 12-7; the sharp decline since 1973 is apparent.

In the 1960s the important shrimp ports in Maine were Portland, Boothbay Harbor, New Harbor, Rockland, Vinalhaven, and Southwest Harbor. Because of the recent decline in catch, the center of the Maine shrimp fishery has shifted to Portland.

Management

Although no management of the shrimp resource of Maine took place until 1973, MDMR began to study the northern shrimp in 1965. Research was focused on abundance, distribution, and life history studies. In 1969 emphasis was shifted to population dynamics and the development of a management model. Current research includes sampling of the commercial catch and of adult and larval populations. Stock size estimates for 1978 project a shrimp population in the Gulf of Maine of 1 to 3 million pounds (Atlantic States Marine Fisheries Commission 1977).

The shrimp fishery of New England is regulated by the Atlantic States Marine Fisheries Commission, consisting of Maine, New Hampshire, and Massachusetts. The fisheries of Maine and Massachusetts are active in different seasons (Maine in winter and Massachusetts in summer) and tend to focus on different components of the total shrimp population (Maine inshore and Massachusetts offshore). Therefore, regional regulation of the fishery is difficult.

In 1973 MDMR set regulations requiring the use of a minimum shrimp trawl mesh size of 1.5 inches (38 mm). The regulation was revised in 1975 to 1.75 inches (45 mm) so that smaller and younger (under 3 years) shrimp would not be caught. This regulation has had little effect on the catch composition of Maine landings during the first few years of implementation (personal communication from D. F. Schick, Maine Department of Marine Resources, Augusta ME; April, 1978).

The correlation between fishing effort and stock size has been found to be more significant than that between temperature and stock size, and it has been suggested that more severely regulated shrimp fisheries (i.e., closed seasons and/or quotas) cannot substantially increase abundance before the mid-1980s, and then only if temperatures are favorably low during the recovery period (Clark and Anthony 1977). Warm seawater temperatures are recognized as being detrimental to shrimp populations; however, the effect of temperature is obscured by the dramatic increase in fishing effort (60%) in recent years (Anthony and Clark 1978). The Northern Shrimp Scientific Committee (Atlantic States Marine Fisheries 1977) concludes in their report for 1977 that the increased fishing effort over the last 5 to 10 years has been a major factor in reducing the stock size, and that the population will not be able to recover without continued severe restriction of the fishery.

MARINE WORMS

This section describes the natural history and other aspects of the bloodworm and the sandworm in Maine. Because management and marketing of both these species are the same or similar, the subsections on "Importance to Humanity" and "Management" review the worm industry as a whole rather than by species.

Bloodworm (*Glycera dibranchiata*)

The bloodworm is a polychaete that burrows in unconsolidated sediments largely in the intertidal zone. From within the burrow the worm feeds on detritus and small invertebrates. It generally migrates only locally within the substrate but at certain times of the year bloodworms have been found in the water column (Dean 1978b; and Graham and Creaser 1978). This polychaete may reach a length of 16 inches (400 mm) and have up to 300 segments (Pettibone 1963). The bloodworm is one of the two species that form the basis of the commercial marine bait worm industry centered in coastal Maine.

Distribution and abundance. The bloodworm range extends from the Gulf of St. Lawrence to the Gulf of Mexico and from central California to Mexico. The species has been found at all levels of the intertidal zone and to a depth of 1300 feet (400 m).

The most abundant populations in Maine are generally found near the low water mark and may reach densities up to 17.2 worms/m^2 (personal communication from E. P. Creaser, Maine Department of Marine Resources, Augusta, ME; April, 1978). The worm usually inhabits the top 10 inches (25 cm) of the sediment (Klawe and Dickie 1957).

Commercial quantities are found only in Maine, New Hampshire, and Massachusetts. Atlas map 4 depicts commercially important worm flats in Maine.

Life history. Detailed information on the reproductive cycle of the bloodworm generally is scarce. Like most polychaetes, this species has two sexes. Sexual maturity is reached probably in the 3rd year, and the rate of maturation appears to be dependent upon both temperature and the physiological condition of the organism (Simpson 1962).

The bloodworm spawns primarily in June in Maine; however, rare occurrences of winter spawning have also been observed (Creaser 1973). Few spawners have been found in Maine east of Frenchman Bay (Skillings and Taunton Rivers; region 5; personal communication from E. P. Creaser, Maine Department of Marine Resources, Augusta, ME; November, 1977). Adult populations in eastern Maine may be recruited from distant populations by larval dispersal.

The formation of eggs and sperm begins in the fall and by March the females are swollen with eggs (Creaser 1973). The number of eggs per individual varies from about 3 million to almost 10 million depending on the size of the individual. The species undergoes limited epitoky prior to spawning, a phenomenon typical of certain polychaetes, in which the worm's body becomes structurally modified. The body wall becomes thin and fragile and the skin changes in pigmentation. Males and females may be distinguished just prior to spawning by color differences. Males are light cream in color and females are brown (Creaser 1973; and Klawe and Dickie 1957).

Spawning bloodworms leave their burrows and swim to the surface in swarms to release their gametes. What controls the timing of swarming is not known, though temperature at the place of spawning, tidal amplitude, and hormonal factors may affect it. A minimum water temperature of 55 F (13 C) for spawning in Maine was reported by Creaser (1973). In a study conducted in the Montsweag Bay-Wiscasset area, populations of bloodworms near the Maine Yankee nuclear power plant spawned earlier than control populations (Mazurkiewicz and Scott 1973), presumably because of the warmer water near the plant. Both Simpson (1962) and Creaser (1973) observed swarming just prior to and during the second high tide of the day. It is not known if the presence of both sexes is required for the release of gametes during swarming. Gametes are emitted as a result of the muscular contraction in swimming.

After gametes have been shed the adult is spent, and its body collapses and sinks to the bottom (Creaser 1973; and Klawe and Dickie 1957). Although Creaser (1973) concludes that all bloodworms die after spawning, Simpson (1962) believes that some spawners may survive.

The fertilized eggs apparently settle to the bottom, develop to the larval stage, and become pelagic for a short time. Mazurkiewicz (1974) found that during intense periods of spawning activity numerous bloodworm larvae were present in the plankton. These and later larval stages were observed in the plankton for only a short period after spawning (Mazurkiewicz 1974). The apparent disappearance of larvae from the plankton is unexplained, but they may leave the water column and live on the surface of the bottom. No information is available about the length of the larval stage.

Adult bloodworms feed primarily on detritus (Klawe and Dickie 1957; and Pettibone 1963) and are especially abundant in areas rich in detritus (Dean and Ewart 1978). Other food items include polychaetes (including other bloodworms) and small crustaceans (Sanders et al. 1962; and Dean and Ewart 1978).

Habitat preferences. Bloodworms are found in both the estuarine and marine systems. In Chesapeake Bay the lower salinity limit for natural populations is approximately 15 ppt (Boesch 1971).

This worm is found on unconsolidated bottoms of the subtidal zone and in the flat and beach habitats of the intertidal zone. It is most abundant in mud flats.

The adult is present in the water column during spawning and at night during the late fall. The water column is the medium in which eggs are fertilized. During the late fall and winter individuals are carried by the movements of the water column (Graham and Creaser 1978; and Dean 1978b).

Factors of abundance. Distribution and abundance of bloodworms are affected by several natural factors. For instance, larvae are known to require temperatures under 68 °F (20 °C) for extended periods immediately after fertilization, and optimal salinity for the larvae was found to be 22 to 26 ppt (Schick 1974).

Predation is also a factor. For example, predation by gulls (*Larus*) and fish, such as striped bass, when the bloodworms are in the water column during spawning (Creaser 1973) may be significant. However, the magnitude of this and other types of mortality is unknown. According to Dean (1978b), however, because migrations of bloodworm occur in late fall and winter, predation probably is insignificant.

Sediment type and/or detritus content may also have some effect on the populations of bloodworms. Evidence of sediment or detrital requirements is incomplete.

Sandworm (*Nereis virens*)

The sandworm is a burrowing polychaete that is often one of the most abundant animals in intertidal flat communities. It may reach a length of 35 inches (900 mm; Pettibone 1963) and is harvested commercially for the bait worm industry. It often leaves its burrow either to swim or crawl for several meters on the substrate surface and then forms another burrow. Sandworms have been observed migrating downstream in estuaries during ebb tides in winter (Dean 1978a).

Distribution and abundance. The range of the sandworm in North America extends from Newfoundland to Virginia (MacGinitie and MacGinitie 1968). Although common in the intertidal zone of coastal and estuarine waters, the sandworm also occurs subtidally down to depths of 475 feet (154 m; Gosner 1971). Intertidal populations are most abundant near the low water mark of flats. The burrows of this species may be deep, up to 18 inches (45 cm) in the sediment (Pettibone 1963).

Population densities of up to 537 worms/m^2 were reported on flats in Wiscasset, Maine (personal communication from E. P. Creaser, Maine Department of Marine Resources, Augusta, ME; April, 1978), and up to 637 worms/m^2 in the subtidal zone of the Sheepscot estuary (Larsen and Doggett 1978b). Commercially important worm flats are illustrated in atlas map 4.

Life history. Despite in-depth studies of the reproductive cycle of the sandworm by Bass and Brafield (1972) in Great Britain, Rasmussen (1973) in Denmark, and Snow and Marsden (1974) in New Brunswick, Canada, knowledge of its development remains incomplete. Sexual maturation is reached in 2 to 3 years. Most data (e.g., Bass and Brafield 1972) indicate that only males undergo epitoky (significant body tissue modification) before spawning and only males swarm.

In coastal Maine spawning occurs from mid-March to late June and peaks in late April and May. Laboratory culture experiments indicate that temperature affects the rate of sexual maturation but does not appear to trigger successful spawning (Bass and Brafield 1972). Raising the temperature of the water in cultures causes worms to develop and release gametes more quickly but the gametes usually are not viable. Tidal fluctuation and subsequent changes in hydrostatic pressure are considered influential in the timing of spawning. Hormonal and physiological factors are probably significant also (Bass and Brafield 1972).

At the time of swarming, males swim to the surface where they release sperm, and then die. Individual females release from 100,000 to 17 million eggs depending on the size of the female within the burrow (TRIGOM 1974), and may subsequently die.

Most sandworms live to be about 3 years old but Dean (1978a) found a few worms up to 5 years old, plus one individual which may have been older.

Fertilized eggs sink to the bottom and the larvae develop in the burrow for 5 to 6 days after which they become pelagic for a short time. Growth of larvae is initially achieved by increasing the number of segments followed by enlargement of the segments (Bass and Brafield 1972).

Larvae then resume a benthic existence, probably subtidally, and attach to the sediment surface. After 12 days the organism may form shallow burrows and after 4 months it either establishes a subtidal burrow or migrates to the intertidal zone. Migration to the intertidal zone also may occur after a year (Bass and Brafield 1972).

Adult sandworms feed on various types of invertebrates, both in the water column and on the bottom. They also feed on algae, Ulva (Pettibone 1963) and detritus (personal communication from K. Fauchald, University of Southern California, Los Angeles, CA; April, 1979).

Habitat preferences. Sandworms live in the intertidal and subtidal zone of both the marine and estuarine systems. This species is found in estuarine areas where the salinity of the water column is <0.5 ppt for over 8 hours of the tidal cycle (Larsen and Doggett 1978b). The greatest subtidal abundances (637 worms/m^2) in the Sheepscot estuary occurred in an area where salinity varied from 0.5 to 19 ppt (Larsen and Doggett 1978b).

The adult life of the sandworm is spent on subtidal unconsolidated sediments, flats, or beach/bar habitats (Larsen and Doggett 1978a). This species is found most frequently and in greatest abundance in intertidal mud flats (Larsen and Doggett 1978a). Larvae inhabit subtidal unconsolidated sediments and the water column.

Factors of abundance. Various natural factors may influence the distribution and abundance of sandworms. This species is especially vulnerable to predation because it often emerges from its burrow to feed. Worms are an important food source for many fish (Pettibone 1963) as well as rock crabs and green crabs.

During spawning males swimming at the water surface are often preyed upon by seagulls (*Larus*). The effect of the observed winter migration of worms (Dean 1978a) on the total population is unknown. However, Dean (1978) believes that predation is minimal in the winter.

Extended ice cover on mud flats sometimes causes high mortality of sandworms because of oxygen depletion (Rasmussen 1973). Laboratory experiments with the sandworm indicate that this species is ordinarily extremely efficient in oxygen utilization (Newell 1970). In an area of the Sheepscot estuary, which is covered by ice most of the winter, relatively high abundances of sandworms ($347/m^2$) were found in samples taken in early April (Larsen and Doggett 1978b). This indicates that subtidal populations may not necessarily have high winter mortalities.

Human Impacts

Harvesting may have a significant effect on the abundance of sandworms. However, no data are available on fishing mortality of either sandworms or bloodworms.

Shippers, diggers, and sportfishermen have noted a decline in the size and abundance of worms in recent years (Schroeder 1978). Many worms that are missed in the process of digging may be damaged or left exposed to temperature extremes and predation.

Landings (figures 12-8 and 12-9) and abundances reported by Larsen and Doggett (1978 a and b) from the intertidal zone along the coast of Maine and in the subtidal zone of the Sheepscot estuary (Larsen 1979) indicate that sandworms are more abundant than bloodworms.

Other factors that may potentially reduce worm abundance are shoreline construction, dredging, toxic discharges or spills. Information on the effects of these factors is lacking.

Importance to Humanity

Marine worms are the favored bait of many saltwater sportfishermen along the east coast of the United States, particularly from Long Island, NY, to Chesapeake Bay. Because of the demand for worms by these fishermen, the bait worm industry is the fourth most valuable fishery in Maine after lobster, clams, and finfish.

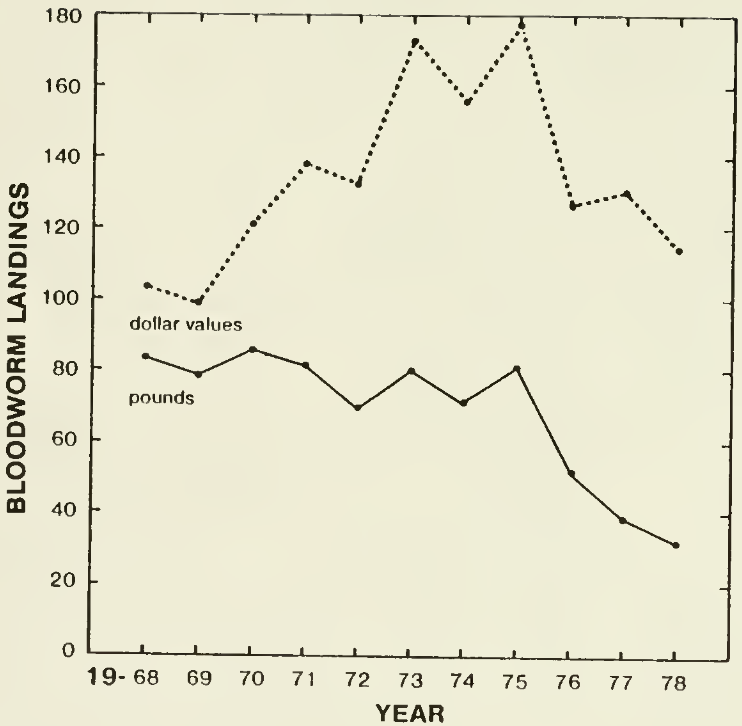

Figure 12-8. Pounds (x 10^4, solid line) and dollar values (x 10^4, dotted line) of bloodworms landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

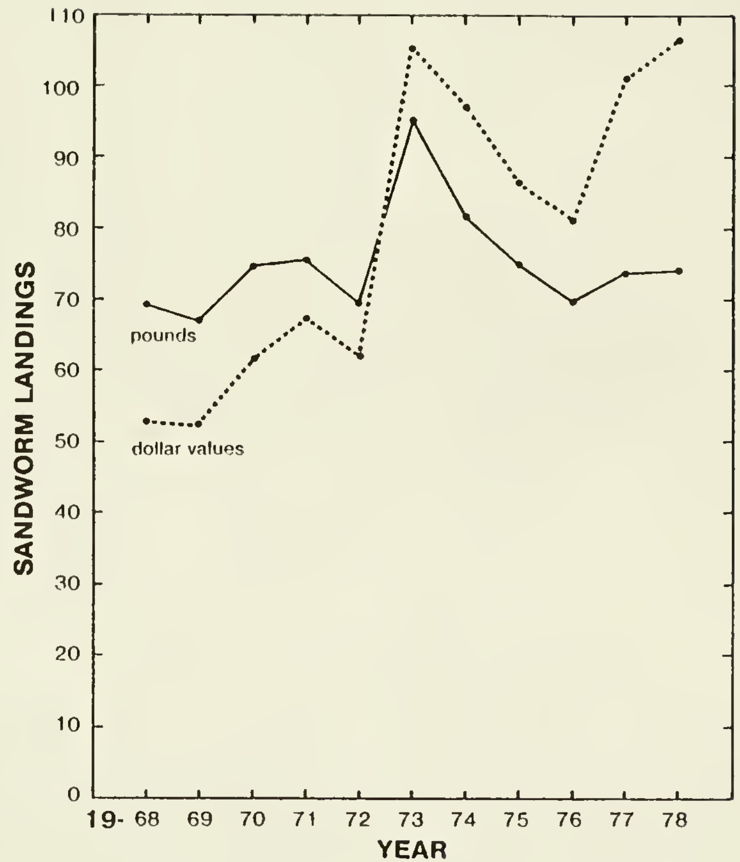

Figure 12-9. Pounds (x 10^4, solid line) and dollar values (x 10^4, dotted line) of sandworms landed in coastal Maine from 1968 to 1978. (December, 1978, data are estimated.)

Maine, currently, is the center of the bait worm industry, supplying over 90% of this country's production and it is the only area that provides a continued high-level supply of the two species.

The marine worm industry began on Long Island, NY, in the 1920s, but the fishery gradually moved northward as local worm populations decreased in numbers and more abundant populations were located. The industry began in Maine in the early 1930s and is now centered in Lincoln and Washington Counties. Hancock County also supplies many worms (personal communication from E. P. Creaser, Maine Department of Marine Resources, Augusta, ME; April, 1978). Approximately 1200 worm diggers and 19 dealers operate in Maine. Major distributers to local markets are located in New York, Boston, and Baltimore.

Management

A license is required for taking more than 125 worms/day. The method of harvest is limited to hand-powered devices, and recently a ban has been placed on digging on Sunday.

No management plan has been adopted for these marine resources, although the industry has taken exceptional initiative in supporting research and exploration of management alternatives. For a history of the marine worm industry in Maine see Sperling (1979).

Aquaculture of bloodworms has been suggested by Dow (1978) as the only way to reestablish and sustain the resource in Maine. However, this method was attempted in the early 1970s with little success. The potential for raising bloodworms in heated effluent from a nuclear power plant was studied. Feeding was a major obstacle in the study (Schick 1974), and worms in warmer water reach sexual maturity more rapidly and at smaller sizes. Once worms are sexually mature they become fragile and are of no commercial value.

RED TIDES

Red tides have been historically common in marine waters throughout the world. Red tide is a massive population explosion of a species of dinoflagellate that produces a substance that is toxic to many other marine species. The organism is planktonic and its red color, in abundance, gives the impression of a red tide.

The "red tide organism" of Maine is *Gonyaulax excavata* (formerly known as *G. tamarensis*; Loeblich and Loeblich 1975). It is a dinoflagellate, microscopic, photosynthetic, single-celled organism covered with cellulose plates, and has two flagellae for locomotion.

Life History

Gonyaulax appears to ingest organic particles for energy. It migrates within the water column daily, surfacing during the day and swimming downward at night. Reproduction in *Gonyaulax* is either asexual or sexual.

The organism also exists in a cyst form that is nonmotile and has been found in sediment to depths of 90 m (297 feet; personal communication from C. M. Yentsch, Bigelow Laboratory, West Boothbay Harbor, ME; November, 1977). The cysts may form as a response of the organism to environmental stress.

In developing a model for a bloom of Gonyaulax, Prakash (1975) suggested that the process involved two distinct parts: initiation and continuation. Bloom initiation requires specific biological and chemical conditions that would allow exponential growth of a population. An example is the disruption of cyst beds caused by hydrographic disturbances. Continuation of the bloom would then involve hydrographic and meteorological factors that could act as mechanisms to concentrate the bloom. If cysts were carried to warmer surfaces or coastal waters in spring or summer, excystment could occur and may account for reappearance of Gonyaulax in spring each year (personal communication from C. M. Yentsch, Bigelow Laboratory, West Boothbay Harbor, ME; November, 1977).

Factors of Abundance

The ecology of Gonyaulax excavata has attracted the attention of an increasing number of scientists in recent years. One of the most puzzling aspects of red tide is that the blooms are composed almost entirely of this single species. Thus, conditions that favor a bloom of Gonyaulax must be highly selective.

Prakash (1967) found that in culture conditions the optimal temperature and salinity for G. excavata were 59 to 66°F (15 to 19°C) and 19 to 20 ppt. He has suggested that in coastal and estuarine conditions salinity has a greater effect on the abundance of this organism than does temperature, although the effect of temperature may be expressed through cyst formation. The motile form of the organism is not found in nature at temperatures less than 41°F (5° C; Yentsch et al. 1975). The low salinity in upper estuaries may slow filtration rates of shellfish to such an extent that the organisms do not take in toxins at a harmful level.

Nutrient requirements of red tide organisms are not well defined. Several studies (Prakash 1967, 1975; Yentsch et al. 1975) have suggested that humic matter from land runoff may be important in controlling concentrations of dissolved trace metals for growth of the organism. Other research has focused on the role of iron, vitamins, and organic materials in Gonyaulax nutrition. The nitrogen and phosphorus requirements of Gonyaulax seem to be much lower than those of other phytoplankton species (Yentsch and Yentsch 1977).

Benthic organisms may ingest the cyst form of the species, and accumulate the toxin in the absence of a bloom. One dense bed of these cysts has been located off the Maine coast near Monhegan Island (personal communication from C. M. Yentsch, Bigelow Laboratory, West Boothbay Harbor, ME; November, 1977). Prakash (1967) notes that sea scallops in the Bay of Fundy reach maximum levels of toxicity in winter, when cysts may be most abundant.

Other factors that may influence the species abundance include predation, competition, and day length.

Importance to Humanity

The toxins Gonyaulax produces, which are harmful to other marine species, evoke a reaction in humans known as paralytic shellfish poisoning (PSP). The poison is a group of endotoxins contained within the cell of the dinoflagellate that is released when the cell is broken during digestion by the consumer. The endotoxins block the transmission of nerve impulses along nerve fibers.

Toxins are accumulated in the tissues of filter-feeding shellfish, such as clams and mussels. In sufficient quantities they may be fatal to host organisms, though certain species show high resistance to the poisons. People who eat contaminated shellfish may suffer varying degrees of PSP and may die from its effects. The toxins are not destroyed by cooking.

Toxicity is 10 to 100 times greater in the cyst than in the motile organism (personal communication from C. A. Mickelson, Bigelow Laboratory, West Boothbay Harbor, ME; November, 1977).

The recent history of red tides in Maine dates back to 1958. Following an outbreak of shellfish poisoning in New Brunswick in 1957, Maine officials initiated a sampling program in 1958. Since then, toxin G. excavata has been found in shellfish each year, and closings of shellfish harvest have occurred (Hurst 1975). Initially only the far eastern region of the coast, especially Washington County, was affected.

It has been suggested that since cyst beds have become established (after severe blooms in 1972 and 1974) Gonyaulax will be a recurring problem along the entire Maine coast. Waters near Monhegan and Matinicus Islands on the Maine coast have been permanently closed to shellfish harvest because of red tide.

Management

The monitoring scheme initially involved monthly sampling of six stations from October to May, biweekly sampling until a rise in toxicity was noted (usually by 15 June), and weekly sampling until 1 October (Hurst 1975). The sampling program was expanded in 1975 to include 18 primary stations, and 98 secondary and tertiary stations. Primary stations are sampled weekly from April to October and when toxicity is first detected, secondary and tertiary stations are sampled (Gilfillan et al. 1976).

Areas are closed to shellfish harvest when the toxicity level reaches 80 μg PSP/100 g shellfish. A toxicity of approximately 500 μg PSP/100 g shellfish is sufficient to cause sickness in humans (Gilfillan et al. 1976).

RESEARCH NEEDS

Most aspects of the role of various species in the ecosystem are unknown and need to be examined. Commercial species of invertebrates should be examined in relation to their role in the ecosystem, and both biotic and abiotic factors should be addressed.

Abiotic factors include temperature and salinity preferences of each species at its various life stages. Movements of water masses during the time larvae are in the water column should be investigated and sediment preferences of settling larvae, migrating juveniles and adults should be explored.

Biotic factors include the following: food webs in relation to each species, competition between individuals of a species and between species, natural mortality rates, and energy transfer between trophic levels.

Natural life history studies are needed and human impacts on abundance should be explored. These include the effects of commercial removal and the potential effects of various perturbations such as dredging, spoil disposal, oil spills, and discharge of contaminants, on each species at various life stages.

When all factors, both natural and artificial, are known, questions such as the following may be answered:

1. Why have shrimp landings decreased so sharply?
2. How are scallop beds formed and why are catches so erratic?
3. Do worms prefer particular sediment types and/or detrital amounts in the substrate?
4. Which cyclic events in life histories of populations relate to harvest levels?

Many theories attempt to answer the above questions. In the past, correlation of a single abiotic or biotic factor with harvest has been attempted. It may be more valuable to correlate a variety of variables with species abundance and distribution. The ecosystem approach rather than the single species-single factor approach is necessary.

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Chapter 13
Marine Mammals

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Two orders of marine mammals inhabit the nearshore Gulf of Maine region: Pinnipedia (seals) and Cetacea (whales and dolphins). Twenty-one species of whales and porpoises and five species of seals have been reported in the Gulf of Maine but only five species in all are common to coastal Maine. The others are either uncommon, rare, or are found mainly far out to sea. Most cetaceans exhibit rather clear migratory patterns, that is, they swim northerly along the coast in the spring and southerly in the fall and apparently are absent or scarce in winter. The Harbor seal, however, is a year round resident. Because of their mobility and observed seasonal migrations along the coast, most cetaceans have only a seasonal role in the ecology of coastal waters.

Coastal Maine waters from the Bay of Fundy to New Hampshire are vitally important to many northwest Atlantic populations. This region is the major range of harbor porpoises and harbor seals and is essential for feeding and breeding (Katona et al. 1977). It is also part of the native range of the gray seal, whose populations were reduced by hunting in the past. The area east of Penobscot Bay, particularly the Mt. Desert Rock region and the approaches to the Bay of Fundy, appears to be an important summer feeding area for humpback and finback whales. Two endangered whales, the northern right whale and the humpback whale, make regular use of the approaches to the Bay of Fundy each year (Gaskin et al. 1979).

Data for determining the abundance and changes in abundance of whale species for the northwest Atlantic, the Gulf of Maine, and coastal Maine generally are scattered and/or intermittent. Until recently, for example, no systematic or sustained counts of cetaceans have been made and most of the data available are from "chance" observations.

The Bureau of Land Management's Cetacean and Turtle Assessment Program (CETAP), conducted by the University of Rhode Island, is presently in its second year of field data collection on the size and distribution of cetacean populations from the Gulf of Maine to the coast of North Carolina. In addition, the New England Aquarium is currently coordinating detailed studies of marine mammals in the approaches to the Bay of Fundy and Cobscook/Passamaquoddy Bays.

The interpretation of data on the relative abundance of whale species presents additional problems even if all species are correctly identified. Rare species tend to be reported more thoroughly than common ones, which can exaggerate their importance or relative abundance. The same bias appears with sightings of large species as opposed to smaller ones. An untrained observer is apt to misidentify a small species as the young of a larger species, so that minke whales are often mistaken for young finbacks (TRIGOM 1974). The different habitat preferences of the various species present another problem. In the offshore regions many species that may be common are unlikely to be observed because these areas are inaccessible. In addition, while it may be true that most cetaceans are scarce or absent in the Gulf of Maine during the winter months, observation efforts are also less frequent during that time. Because whales are relatively scarce and are highly valued and protected species, most studies of the biology and interrelationships of the various species must be conducted at a distance, so as not to cause excessive disturbance, or on dead, beached, or captive animals. It is hard to get data representative of marine mammal populations in the wild. All of these problems frustrate efforts to realistically assess the abundance and relative importance of marine mammals in the Gulf of Maine.

Harbor seals are relatively common along the Maine coast. Data on the distribution and abundance of harbor seals and harbor seal haulout sites come from the coastwide aerial photocensus conducted by Richardson (1973a) and subsequent boat surveys in 1974 and 1975 which updated information on 35 haulout sites along the coast (Richardson 1976). Dr. James Gilbert at the University of Maine at Orono is conducting an update to the coastal harbor seal population assessment.

Two general problems are discussed in this chapter in some detail because of their world-wide significance and their effects on the present and future status of marine mammals in Maine. One is a potential threat that is not yet considered an immediate danger in Maine: the pollution of coastal waters and their biota with industrial contaminants, especially organochlorines and heavy metals. The other is the world-wide decline in the abundance of whales, which has reached near catastrophic levels and which directly affects coastal Maine populations. In this context the history of the whaling industry is reviewed. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

DISTRIBUTION AND ABUNDANCE

Twenty-one species of whales and porpoises and five species of seals have been reported in the Gulf of Maine. These cetacean and pinniped species, respectively, and their known habitat uses and estimated abundance in the western North Atlantic region are listed in tables 13-1 and 13-2. Of these marine mammals, four cetaceans (harbor porpoise, finback whale, minke whale, and humpback whale) and one pinniped (harbor seal) are common in coastal Maine waters. These animals appear to be more common (i.e., more commonly sighted) in eastern Maine waters than western Maine waters.

Table 13-1. The Habitats and Estimated Abundance of the Cetaceans of Maine[a]

Species	Habitat distribution: Known to enter estuaries and rivers	Habitat distribution: Often found in bays inshore, or coastal waters	Habitat distribution: Usually found well at sea	Habitat distribution: Habitat poorly known, usually at sea	Estimated abundance in North Atlantic
<u>Common</u>					
Harbor porpoise	x	x			4000 to 10,000
Finback whale		x	x		7200
Minke whale		x	x		No estimates
Humpback whale (ES)[b]		x			1100 to 1500
<u>Uncommon</u>					
Long-finned pilot whale		x			No estimates; schools up to 300 in Georges Bank
Northern Right whale (ES)		x	x		10's to 100's
Atlantic white-sided dolphin			x		Not common; No estimates
Killer whale	x	x			No estimates; more common further north and east
<u>Rare</u>					
Striped dolphin		x	x		No estimates
Beluga	x	x			No estimates; visitor from Gulf of St. Lawrence
Sei whale (ES)			x		1570 off Nova Scotia
Sperm whale (ES)			x		22,000

[a]TRIGOM 1974; Prescott et al. 1979.
[b](ES)=Endangered species.

(Continued)

Table 13-1. (Concluded)

Species	Habitat distribution: Known to enter estuaries and rivers	Habitat distribution: Often found in bays inshore, or coastal waters	Habitat distribution: Usually found well at sea	Habitat distribution: Habitat poorly known, usually at sea	Estimated abundance in North Atlantic
Rare (cont.)					
Pygmy sperm whale				x	
Northern bottlenose whale				x	Poorly known, >700
True's beaked whale				x	Poorly known, extremely rare
Blainville's whale				x	Stray visitor; extremely rare
Blue whale (ES)			x		Originally 1100, now low 100's
White-beaked dolphin			x		No estimates; rare stray
Common dolphin	x		x		No estimates; probably more common than records indicate
Bottlenose dolphin	x				No estimates; rare
Risso's dolphin			x	x	No estimates

Table 13-2. The Habitats and Estimated Abundance of Pinnipeds of Maine[a]

Species	Relative abundance in coastal Maine	Habitat distribution			Estimated abundance in western North Atlantic	
		Known to enter estuaries and rivers	Often found in bays, near shore, or coastal waters	Usually found well at sea	Canadian waters	U.S. waters
Harbor seal	common	x	x		15,000	7000
Gray seal	uncommon		x	x	23,680 adult 6400 young	~80
Harp seal	rare		x	x	450,000	
Hooded seal	rare		x	x	3000	
Walrus	rare	x	x	x	20,000	

[a]TRIGOM 1974; Katona 1977; Mansfield and Beck 1977; Sergeant 1973; Prescott et al. 1979.

Cetaceans

Most of the cetaceans discussed here range along the Maine coast from about late April through October or early November. During the course of the year many of them show a clear north-south migration pattern. The harbor porpoise is an exception, exhibiting an onshore-offshore migration pattern. The major abiotic factors that influence cetacean distribution are temperature, currents, and physiography, but little detailed information is available. The finback whale is the most common of the large whales to frequent coastal Maine and presently the most abundant large whale in New England waters. The harbor porpoise is the numerically dominant cetacean in the Gulf of Maine. A summary of recorded sightings of marine mammals within the last few decades in the characterization area is given in table 13-3.

During early spring or winter, sightings of cetaceans are common in the southern portion of the Gulf of Maine, Massachusetts Bay, and Cape Cod Bay. Apparently, the animals migrate up the coast in spring and early summer, remaining along the Maine and Fundy coasts until late autumn. This distribution trend correlates well with the distribution of herring and other schooling fishes, squid, and zooplankton (copepods and euphausiids). During this period species generally aggregate in productive areas, such as fishing banks, river mouths, or estuaries. Large whales, such as the right whale and humpback whale, sometimes approach the coast; however, most of the species will be found in water between 20 and 50 fathoms (37 and 91 m) deep. Harbor porpoises tend to be found in relatively shallow water (20 to 50 fathoms or less). The 50-fathom contour appears to be an important demarcation of feeding areas, as does the 100-fathom (183-m) contour farther offshore (Katona 1977).

Over the past several years inshore movements of several species, including humpback whales, appear to be on the increase in North Atlantic waters but it is difficult to distinguish how much of the observed increase is due to an increase in interested observers. The apparent movement inshore seems to be in part due to the collapse of the capelin stocks on the Grand Banks as a result of overfishing (Lien and Merdsoy 1979). The whales are probably moving inshore in search of alternative food supplies. Gaskin and coworkers (1979) conclude that the presence of humpbacks in the herring-rich area of the approaches to Cobscook Bay and Passamaquoddy Bay is likely to be a regular and annual event. Unfortunately, the increasing occurrence of humpbacks close to shore increases the likelihood of their entanglement with fishing gear and collisions with boats.

It is important to remember that the large whales, at least, can easily travel the entire Maine coast in a day or two if they choose to; consequently, their feeding ranges may be the whole of the Gulf of Maine. Despite their mobility, however, many individuals may remain in local areas for weeks or sometimes months. Data gathered during the period 1973 to 1976 show that humpback whales and finback whales regularly use the Mt. Desert Rock (region 5) region for feeding from June through September. Humpback whales (with calves) spent extended periods in the Campobello Island (region 6) region during July to September, 1979 (Gaskin et al. 1979).

Table 13-3. Summary of Recorded Random Sightings of Marine Mammals in the Six Regions of the Characterization Area[a]

Species	Numbers sighted in the characterization regions							Period of record	Months of highest abundance
	1	2	3	4	5	6	Total		
Northern right whale			1		1	11	13	1961 - 1979	June - Sept
Finback whale			1	6	127	36	170	1961 - 1979	June - Sept
Humpback whale	1		1	1	11	6	20	1960 - 1979	June - Nov
Minke whale		2	3	8	6	11	30	1949 - 1976	June - Aug
Harbor porpoise	4	1	23	26	65	29	148	1957 - 1977	May - Oct
Long-finned pilot whale		1	2	3	3		9	1957 - 1976	June - Sept
Killer whale	2			2		2	6	1964 - 1976	July - Sept
Atlantic white-sided dolphin[b]			1			2	3	1956 - 1977	July - Sept
Sperm whale[b]	1			1	1		3	1975	- - - - -
Beluga	1	1					2	1929 - 1977	- - - - -
Common dolphin[b]	1						1	1962 - 1976	- - - - -
Striped dolphin[b]	1						1	1970 - 1975	- - - - -
Harbor seals (total)	423	501	629	1576	1305	1135	5569	1972 - 1973	year round
Harbor seal pups	87	28	1	29	79	3	227		
Harbor seals per nautical mi^2	6	16	9	12	12	17	12		
Gray seals	1		5	66	70	6	148	1965 - 1976	summer

[a]Katona et al. 1977; Richardson 1973a; Gilbert et al. 1978; and Gaskin et al. 1979.
[b]Mostly strandings.

During the winter months Maine's cetaceans either migrate south to breeding grounds (e.g., the humpback whales, right whales, and minke whales) or move offshore where waters do not become as cold as along the coast (pilot whales and some finback whales). The winter ranges of the other cetaceans are not well known.

Pinnipeds

The gray seal and the harbor seal are currently the only pinnipeds of the Atlantic coastal waters of the United States (Katona 1977; and Richardson 1978). The harbor seal is the dominant seal of coastal Maine and can be sighted throughout the year on small islands and half-tide ledges coastwide. Censuses conducted by Richardson (1973 to 1976) reveal a harbor seal population of about 6000 that is well distributed in all embayments of the Maine coast, with somewhat greater densities from Casco Bay to Pemaquid (region 2), the approaches to Penobscot and Blue Hill Bays (regions 4 and 5), and in the Jonesport, Englishman Bay, and Machias Bay areas (region 6; table 13-3). The mean density was 12 seals per square nautical mile surveyed (9/sq mi; 3.5/sq km). Richardson (1973a) also identified harbor seal pups. The highest numbers of pups were in regions 1 (87) and 5 (79). It is not known whether discrete populations or subpopulations function within these different embayments. The sites inventoried and number of seals observed are presented in appendix table 1.

Haulouts are areas used by seals for resting, sunning, feeding, breeding, and pupping. They are usually small islands lacking terrestrial vegetation but having some areas that are exposed at mean high tide, or half-tide ledges that are completely submerged at mean high tide. In either case the intertidal area is usually densely covered with macroalgae (fucoids, Chondrus sp.) and the approach to the water is a gentle slope. Haulouts invariably are surrounded by water deep enough for escape even at low tide.

Although whelping and rearing of young occur at offshore as well as estuarine sites, those marine haulouts exposed to high energy wind and wave action appear to be utilized more for foraging and socialization. Less exposed, up-estuary haulouts appear to be favored for whelping, mating, and use during molting (Richardson 1973a). Seasonal censuses of harbor seals conducted by Richardson reveal up-estuary migration of colonies in spring, with subsequent segregation of age and sex classes at whelping sites. Down-estuary movement occurs in the late fall, following breeding and molting. Greater numbers of seals are found at more protected, up-estuary haulouts during late spring and summer, whereas they utilize more exposed haulouts in deeper, ice-free water during winter months. The extent to which water temperature, food availability, and behavior affect the seasonal redistribution of these colonies has not been documented.

The distribution of seal haulouts among regions in the characterization area, based on Richardson (1973a), is summarized in table 13-4. Over 50% of these haulout areas are in regions 4 and 5. Richardson (1975) identified 44 seal haulout areas in Maine (41 in the characterization area) known to be regularly utilized by seals and judged to be significant based on one or more of the following criteria:

1. haulout area where counts of pups have exceeded ten; significant whelping area;

2. haulout area where gray seals are frequently sighted;

3. haulout area where counts have exceeded 65 harbor seals, apparently an area affording protection and favorable foraging;

4. a "traditional" seal ledge important for its geographic location, unspoiled wilderness value, or near publically or privately held islands (National park, Federal, State, or private conservation islands);

5. haulout area coinciding with or near important nesting islands for waterbirds.

These important seal areas are identified on atlas map 4 and are listed in appendix table 2. Over 78% of these important seal areas are located in or east of Penobscot Bay.

The present status of gray seals in Maine coastal waters is not as well known. Most of the gray seals observed along the coast of Maine are transient individuals from Canada (Gilbert et al. 1978). Very little information is available to state whether the population was higher in historic times but they were at one time sufficiently abundant along the New England coast to support hunting by Indians for some time. The Western Atlantic stock, centered in the Gulf of St. Lawrence and along the coast of Nova Scotia, Canada, has been increasing since at least the mid-1960s (Gilbert et al. 1978). Smith (1966) estimated this stock at 5000, while Mansfield and Beck (1977) estimated the present population to be 30,000. Estimates of pup production on Sable Island (Canada) have increased from about 350 in 1962 to over 2000 in 1976 (Mansfield and Beck 1977). Richardson (1976) reported only about 80 gray seals from various sightings in coastal Maine from 1965 to 1975. A total of 148 gray seals in 27 haulout areas have been sighted along the coast over several years (table 13-3 and 13-4; appendix table 3). The majority of these seals (91%) were sighted among the islands and ledges of regions 4 and 5. The only known breeding colony in U.S. waters is at Muskeget Island, near Nantucket, Massachusetts. Probably fewer than 30 seals exist there (J. Prescott, New England Aquarium, Boston, MA; November, 1979). Gray seals inhabiting the Gulf of Maine and Nantucket are most likely recruited from Sable Island, Basque Island, Camp Island, or Gulf of St. Lawrence stocks (all in Canada). Dispersal and migration for this species, especially immatures, can be widespread and extensive, as evidenced by tagging investigations (Mansfield and Beck 1977). Gray seals marked as pups on Sable Island, Nova Scotia, Canada, have been recovered in the Muskeget area, Mt. Desert Rock in Maine, and Barneget Light, New Jersey. Late winter sightings of immature gray seals in the vicinity of Penobscot and Blue Hill Bays suggest that some animals may be year-round residents. Potential breeding and pupping sites have yet to be identified.

Table 13-4. Distribution of Seal Haulout Sites Among the Regions of the Characterization Area[a]

Haulouts	Region							Period of record
	1	2	3	4	5	6	Total	
Harbor seal haulouts	28	15	20	47	54	30	194	1972 - 1973
Gray seal haulouts	1	0	1	14	9	2	27	1965 - 1976
"Significant" haulout areas	3	2	4	13	11	8	41	1973

[a] Richardson 1975; Richardson 1973a; and Gilbert et al. 1978.

REPRODUCTION

Like many of the higher mammals, cetacean and pinniped females usually produce one offspring per breeding cycle. This affords a high degree of protection and parental care for developing young. Multiple births occur at a frequency of about 1% or less for whales (Slijper 1962). The reproductive characteristics of Maine's cetaceans and pinnipeds are quite diverse (table 13-5). All cetaceans and seals of coastal Maine mate in the water except gray seals, which mate on land or in water. Both seal species exhibit delayed implantation; cetaceans apparently do not. Cetaceans give birth to calves underwater, whereas seals bear their pups on islands and ledges. Lactation is comparatively prolonged in cetaceans (4 to 18 months) in contrast with Maine's seals (1 to 2 months).

Only the harbor seal is known to breed on islands and ledges along the coast of Maine. Cetacean calves with their mothers have been sighted in coastal Maine waters (harbor porpoise, humpback whale, right whale, and minke whale). The nearest known major breeding ground for gray seals is Sable Island, Nova Scotia, Canada. Minor breeding colonies exist at Grand Manan, New Brunswick, Canada, and Muskeget Island, Massachusetts. Richardson's 1973 coastal inventory of seal haulout sites revealed 58 sites (29%) with pups present. Eleven of the 41 important haulout areas (26%) were judged to be significant whelping sites (Richardson 1975). Six of these whelping areas are in region 5; three are in region 4 and one each in regions 1 and 2 (see appendix table 2 and atlas map 4). Studies of the harbor seal populations of the west coast and Sable Island, Canada, reveal a recruitment rate (pup production) of about 20% of the total post-whelping population (Richardson 1973b). Similar studies have not been conducted on Maine harbor seal populations but a similar recruitment is projected.

FEEDING HABITS

The majority of marine mammals in Maine are fish eaters (table 13-6). Those fish most commonly eaten by cetaceans are schooling fishes, such as herring and sand lance. Squid are an important food item for pilot whales and white-sided dolphins and may determine local distributions of these whales. Only the right whale is strictly a plankton feeder (copepods and euphausiids). Observations by Canadian investigators suggest that right whales exploit euphausiids rather than copepods in the Bay of Fundy region (Gaskin et al. 1979). Most cetaceans are probably opportunistic and adaptable in their feeding, taking any food items that are present in sufficient amounts (Katona 1977). Their mobility provides for even greater flexibility in food habits.

Important feeding areas along the Maine coast are the upper portion of Jeffreys Ledge, Columbia Ledge (Mt. Desert Rock region), Passamaquoddy Bay (the approaches to the Bay of Fundy), and probably the mouths of most bays, rivers, and estuaries.

Gray seals and harbor seals largely feed on herring and flatfish. Work by Mansfield and Beck (1977) in eastern Canada shows the percent occurrence of different food items in gray seal and harbor seal stomachs (table 13-6). Nonmigratory bottom fishes form the basic diet for most of the year; skates and flounder for the gray seal and flounder and hake for the harbor seal. In summer, however, large schools of fish and squid that migrate inshore form the

Table 13-5. Reproductive Characteristics of Marine Mammals of Coastal Maine[a]

Species	Sexual maturity (years)	Mating season (peak)	Time of parturition	Gestation period (months)	Duration of lactation (mos)	Major calving or pupping areas
Cetaceans						
Finback whale	3-8	Nov-March	Dec-April	11-12	6-7	Off Canadian coast
Minke whale	2-4	Jan-May	Dec-Feb	10-11	4-5	- - - - - - - -
Humpback whale	2	Jan-March	Jan-March	11-12	11	Off Puerto-Rico; Navidad Bank; Silver Bank
Right whale	3-5	May-July	Jan-March	10-12	---	Unknown; still waters near shore
Long-finned pilot whale	f:[b] 6 m:13	June-July	July-Aug	12-16	12	- - - - - - - -
Atlantic white-sided dolphin	---	July-Aug	June-July	10-11	18	- - - - - - - -
White-beaked dolphin	---	---	midsummer	---	---	- - - - - - - -
Common dolphin	3	Aug-Oct	June-Aug	9-11	4	Black Sea
Killer whale	4	May-July	Autumn	13-16	11-12	- - - - - - - -
Harbor porpoise	3-4	June-Aug	Apr-July	9-11	8	- - - - - - - -
Pinnipeds						
Harbor seal	f:2-5 m:3-6	June-July	May-June	7.5-10[c]	1-1.5	Islands and ledges in ME and Canada
Gray seal	f:4-5 m:5-6	March	Jan-Feb	11[d]	$\leq$ 1	Islands, ledges, pack ice in Canada (and Nantucket,MA)

[a] Katona et al. 1977; Anderson 1969; Slijper 1962; and Mansfield and Beck 1977.
[b] f = females; m = males
[c] Delayed implantation 2 to 3 months.
[d] Delayed implantation 3 months.

Table 13-6. Principal Food Items (expressed as percentages in parenthesis) of Marine Mammals in Maine Waters[a]

Species	Food items
Finback whale	Herring (75%), sand lance (10%), krill (10%), miscellaneous (5%)
Humpback whale	Herring (75%), sand lance (10%), krill (10%), miscellaneous (5%)
Right whale	Copepods (80%), euphausiids (20%)
Minke whale	Herring (35%), sand lance (25%), cod (25%), squid (10%), salmon (5%)
Harbor porpoise	Herring (50%), cod (15%), mackerel (15%), hake (5%), smelts (5%), miscellaneous (10%)
Long-finned pilot whale	Squid (80%), cod (10%), herring (10%)
Atlantic white-sided dolphin	Squid (25%), herring (25%), silver hake (25%), smelt (25%)
Killer whale	Cod (25%), herring (25%), salmon (25%), squid (12.5%), mammals (12.5%)
Harbor seal	Herring (24%), squid (20%), flounder (14%), alewife (7%), hake (6%), smelt (4%), mackerel (4%)
Gray seal	Herring (16%), cod (12%), flounder (10%), Skate (10%), squid (6%), mackerel (5%)

[a]Katona 1977; Katona et al. 1977; and Mansfield and Beck 1977.

principal diet; herring, cod, squid, and mackerel for the gray seal and herring, squid, alewife, smelt, and mackerel for the harbor seal. Field studies conducted by Richardson (1973b) in Maine suggest that seals forage for food, often diving and surfacing in local areas for periods of time. Maine seals probably feed on all flatfish species, sculpins, and schooling fishes. Crustaceans comprise an insignificant fraction of the seal's diet (Richardson 1973b). Alewives are a major food item of seals utilizing the upper estuaries in late spring. Herring also appears to be a preferred prey species and may determine local movements and distribution of seals. Richardson (1973b) calculated the hypothetical predation by seals on finfish stocks. Using estimates of seal populations from his surveys (6000 sighted, assumed 7500 maximum), daily food intake of 6% of body weight for 300 days (Sergeant 1973 and Spaulding 1964) and a mean weight by year class and life table from Bigg (1969), Richardson (1973b) calculated that Maine seals consume about 18 million pounds of finfish annually. In comparison to Maine's commercial fishery, seals would appear to consume the equivalent of 14% of the average number of pounds of fish landed annually in Maine from 1967 to 1976. Since the total abundance of fish stocks remains unknown, it is not possible to determine whether seals are in serious competition with people for some fish species.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE

The major abiotic factors that influence the distribution and abundance of marine mammals are water temperature, currents, and physiography but supporting data are scarce. The following factors are better known and will be discussed in terms of their influence on populations of these mammals: food availability, disease and parasites, predation, hunting, pollutants, and habitat disturbance or alteration.

Food Availability

One of the major biotic factors controlling the distribution and abundance of marine mammals is food availability. Seasonal distribution of squid, schooling fishes, and zooplankton may determine local populations of marine mammals. Aggregations of marine mammals at offshore banks have been observed. Evidence exists of a drastic change taking place in the summer distribution of humpback whales on feeding grounds in Canadian waters (Gaskin et al. 1979). Inshore movements of humpbacks from Grand Banks and associated offshore shallows may be in part due to overfishing of capelin stocks there. The humpbacks may be moving inshore in search of alternative food supplies (e.g., herring). Considering the species composition of the major food items of Maine's whales, porpoises, and seals (table 13-6), there is the potential that overfishing of certain commercial fish species could impose limits on many marine mammal populations.

Disease and Parasites

Marine mammals fall victim to a full complement of afflictions, knowledge of which is quite limited because most observations are based on captive animals and must be extrapolated to animals in the wild. There is no evidence that disease and parasites severely impair individuals in the wild. Documented viral infections are rare (e.g., seal pox and viral hepatitis) but bacterial disease is common and is reported to be the single leading cause of death in cetaceans (in captivity). For the most part, deaths of marine mammals go unobserved. In both cetaceans and pinnipeds the most debilitating bacterial disorders seem to be lung infections, like pneumonia. These are common but usually occur as a secondary infection in the wake of some other disability, mechanical injury, or parasitism, which lowers the animal's resistance (Katona et al. 1977).

Marine mammals are also afflicted by a variety of degenerative and deficiency diseases, including eye failure, cardiovascular disease, ulcers, hepatic and renal dysfunction, vitamin deficiencies, stress, metabolic disorders, and a broad range of developmental abnormalities.

Internal and external parasites are common in marine mammals. Cetaceans, in particular, are known to host certain parasitic barnacles, lice, and lampreys. Internal parasites are dominated by nematodes, which invade the respiratory, cardiovascular, gastrointestinal, and cranial systems. Examples include lungworm, tapeworm, heartworm (specific to harbor seals), and flukes. Parasitism is not usually a clinical problem. Most strong, healthy animals tolerate the parasites. Young, old, or otherwise debilitated animals may be sensitive to excessive infestations and may die from them.

A seal parasite of particular concern is the nematode <u>Porrocaecum decipiens</u> (codworm). The adult codworm is found in the gastrointestinal tract of harbor seals, gray seals, and harp seals. Its life cycle is not known completely. Its eggs may hatch in the sea and the larvae invade an intermediate (invertebrate) host, which may be eaten by a fish. The larval codworm burrow into the flesh of many groundfishes, including cod. Large infestations do not necessarily affect the health or nutrition of fish but may render it undesirable and unmarketable. Improperly frozen or cooked fish can be a health hazard to people; the codworm can invade the human gastrointestinal system. Areas of codworm infestation in groundfish have been correlated with high abundance of gray seals in European waters (Platt 1975 and Young 1972) and with the distribution of harbor seals and gray seals in eastern Canada (Scott and Martin 1957). Mansfield (1968) estimated that harbor, gray, and harp seals accounted for 2%, 45%, and 53% respectively of the codworm infestation in the Gulf of St. Lawrence. Presently, codworm is not a problem in most New England fisheries but appears to be more common in eastern Maine. It is unknown what effect on fisheries would result from increased numbers of gray and harbor seals in coastal Maine.

Predation

In addition to people, sharks and killer whales are natural predators on marine mammals in the wild. Predation on orphaned harbor seal pups (which are unlikely to survive anyway) by black-backed gulls and ospreys has been observed (Richardson 1978). Data on the magnitude of predation exclusive of hunting and its effect on the natural populations of marine mammals are lacking. Hunting is discussed below under "Importance to Humanity."

Pollutants

Since aquatic media are the eventual sinks for most types of pollutants, contaminants in the oceans and estuaries have posed serious problems to many forms of aquatic life. Marine mammals have been exposed to these pollutants and studies show that both cetaceans and pinnipeds may absorb them in their tissues in significant amounts. Organochlorines, heavy metals, and petroleum will be discussed in light of their known impacts on the ecology of marine mammals. Some of these pollutants have been discovered in marine mammals at higher levels than those found in any other animal. The major avenue for intake of these types of pollutants is through consumption of contaminated prey. There appear to be two related mechanisms for the observed accumulation and concentration of organochlorine and heavy metal pollutants. Lower trophic level organisms (fish and invertebrates) filter these pollutants from the water or sediments and thereby concentrate them. Marine mammals feeding on these fish and invertebrates incorporate the accumulated pollutants, store them, and may concentrate them further. It is expected that those marine mammals (toothed whales, porpoises, and seals) that feed on contaminated organisms of a higher trophic level would exhibit the highest concentrations of pollutants. Marine mammals, being long-lived, also would accumulate large amounts of pollutants over time.

Organochlorines. These include the pesticide compounds DDT and dieldrin and other halogenated hydrocarbons, such as PCBs (polychlorinated biphenyls). These manufactured compounds degrade very slowly and are extremely persistent in the environment. Residues of these compounds have been found in certain seals and cetaceans, probably because of their relatively high-level position in the aquatic food chain and long life span. The vulnerable site of organochlorine deposition and retention in marine mammals is the fatty tissue of the blubber layers. Death or injury can occur when the animal's food supply is cut short or it ceases feeding (e.g., during breeding and calving or pupping) and the body's fat reserves are used for energy. The stored toxicants are then released into the bloodstream in usually harmful quantities. Equally disasterous is the conversion of the contaminated fat reserves in reproduction. Katona and coworkers (1977) present a summary of numerous studies reporting analyses of organochlorine residues in marine mammals known to inhabit the Gulf of Maine (table 13-7). Because of the migratory behavior of most of the cetaceans it is difficult to determine where these animals picked up the contaminants. It is safe to assume that among the harbor seals and harbor porpoises the sources are quite local. Several species listed by Katona and coworkers, particularly the harbor porpoise, pilot whale, harbor seal, and striped dolphin, showed very high levels of DDT and PCB which may adversely affect those populations. Helle and coworkers (1976) have attributed uterine occlusions in female gray seals to high PCB levels. In a review of current research, Katona and coworkers (1977) attributed low reproductive rates in Baltic Sea seals to heavy organochlorine pollution.

The organochlorine residue levels found in marine mammals may vary considerably with local conditions, even within relatively short distances. Residue amounts appear to be influenced by the level of contaminant usage in the area of the hydrologic regime of the area, the diet of the animal, the reproductive state, age and, in some cases, sex of the individual. Gaskin and coworkers (1976) noted that harbor porpoises from the Bay of Fundy region had significantly higher DDT levels than those sampled from St. Mary's Bay (Nova Scotia, Canada) and Rhode Island. Possible reasons for this include: (1) DDT is concentrated in the Bay of Fundy because of runoff from New Brunswick streams, which drain areas of heavy DDT use; (2) the mixing and upwelling in the mouth of the Bay of Fundy stimulates remixing and resuspension of sediment pollutants in the water column; (3) current systems in the Bay prevent loss of pollutants to main Atlantic waters; (4) colder waters there slow bacterial degradation of the contaminants.

In some cases pollutant level analyses show trends related to age and sex of the animals. Harbor porpoises from the Bay of Fundy exhibit a marked increase in DDT level with age in males but a definite decrease with age in females (Gaskin et al. 1976). Presumably, the female transfers residual organochlorines to her fetus via the placenta. No documentation exists on effects of these pollutants on developing fetuses and young animals. A similar study of harbor seals from the Gulf of Maine and the Bay of Fundy reveals that lactating females had significantly lower pollutant levels than all other seals tested (Gaskin et al. 1973).

A review of current trends and research results shows evidence of a definite decrease in organochlorine levels in Bay of Fundy harbor porpoises since 1969. The decrease is exhibited by both males and females regardless of age, although males still retain higher levels overall (Gaskin et al. 1976). It is hoped that continued restriction on the production and use of organochlorines will further reduce their presence in marine organisms in the Bay of Fundy and coastal Maine.

Heavy metals. These metals, particularly mercury, are increasingly conspicuous in marine systems (see chapter 3, "Human Impacts on the Ecosystem"). Analyses of marine mammal tissue taken from the wild (by capture or stranding) indicate exceedingly high mercury concentrations may be present in certain populations. Katona and coworkers (1977) summarizes study results on heavy metal contamination in marine mammals known to inhabit the Gulf of Maine (table 13-8).

Both mercury and cadmium concentrations in marine mammals appear to be positively correlated with age. Again, the relatively high trophic position in the aquatic food chain and long life span of most of these animals contribute to the high level of accumulation of heavy metals. Some researchers propose that harp seals have lower mercury contamination than gray seals or harbor seals because harp seals feed on a lower trophic level, that is, capelin and crustaceans vs. the cod and flatfish on which the harbor and gray seals feed (Katona et al. 1977). Related research indicates that contaminant levels of cadmium, zinc and copper in harbor seals from the German North sea are much higher than prey fish values. Mercury concentrations in seals were more than 1000 times greater than corresponding prey fish values.

The major storage depositories for heavy metals in marine mammals are the liver and the brain. This pattern of mercury distribution is unique, unlike that of other animals tested. In people, for example, most mercury is present as methlymercury, which is rapidly transported throughout the body. In fish, the staple food of most marine mammals, almost all mercury is in the methylmercury form (Katona et al. 1977). However, in seals, harbor porpoises, and pilot whales, it has been confirmed that mercury is concentrated in the liver in a de-methylated form. This storage of the de-methylated mercury in the liver, with minimal transport to other body tissues, may be the factor that enables seals to maintain high contaminant levels without exhibiting normal mercuric poisoning effects. Current research suggests that there is a saturation limit and older seals may surpass that level and begin to pass

Table 13-7. Organochlorine Residues (in ppm wet tissue) in Blubber Tissues of Marine Mammals from the Characterization Area and Some Surrounding Areas[a]

Species	Comments	Location	PCB	Dieldrin	DDT
Harbor seal	1971	Boothbay Harbor, ME	92.54±82	0.19±0.15	65±41
Harbor seal	1971	Grand Manan Is., Deer Is. (New Brunswick, Can.)	41±24	0.45±49	31±18
Harbor & gray seals	Juv. & adults, 1967	Magdalen Island (Gulf of St. Lawrence)		0.03	1.68 (mean)
Harbor & gray seals	Juv., imm., adults, 1967	Cabot Straits (Gulf of St. Lawrence)		0.07	12.18 (mean)
Harp seals		Gulf of St. Lawrence	8.2±6.1	0.17±0.09	9.3±6.6
Harp seals	Juv., imm., adults	Gulf of St. Lawrence	4.64±1.85	0.10±0.11	7.94±3.10
	Juv., imm., adults	Labrador Point	3.06±3.70	0.18±0.10	4.32±6.67
	10-day old pups, 1971	Gulf of St. Lawrence	2.46±1.38	0.64±0.483	1.41±0.66
	10-day old pups, 1973	Gulf of St. Lawrence	1.08±0.53	0.05±0.046	1.34±0.59
Fin whale	1971	North Atlantic			0.667-2.557
Fin whale	Commercial oils, 1967	North Atlantic	0.0-7.0		4.24-32.33
Humpback whale		North Atlantic	3.55±2.5	0.325±0.58	8.55±10
Sperm whale	Commercial oils, 1967	North Atlantic	1.0 (mean)		7.66 (mean)
Sperm whale		North Atlantic	2.31±1.7	0	8.5±7.2
Beluga whale	Shallow Bay	MacKenzie Delta			3.90±0.89
	Kugmallit Bay				2.56±0.46

[a]Katona et al. 1977.

(Continued)

Table 13-7. (Concluded)

Species	Comments	Location	PCB	Dieldrin	DDT
Long-finned pilot whale	Commercial oil	North Atlantic			28.13 (mean)
Long-finned pilot whale		North Atlantic			6.88
Long-finned pilot whale		New England	114±42	3.0±1.1	268±30.3
Short-finned pilot whale		Lesser Antilles	0.69-1.60	0.01-0.04	1.25-2.28
Atlantic white-sided dolphin		Nova Scotia	37	1.4	40.7
Common dolphin		Rhode Island	69	2.6	70.9
Striped dolphin		Atlantic coastal states	69, 39	2.4±1.4	231±70.7
Harbor porpoise		Rhode Island	74	1.5	57.5
Harbor porpoise	Weaned & adult males	New Brunswick Nova Scotia		9.24 (mean)	306.74 (mean)
	Male sucklings			5.30 (mean)	130.90 (mean)
	Female sucklings imm. & resting females			5.00 7.75 (mean)	154.80 214.27 (mean)
	Pregnant & lactating females			1.37 (mean)	69.30 (mean)

Table 13-8. Mercury Residues (in ppm wet tissue) in Liver Tissue of Marine Mammals from the Characterization Area and Other Areas[a]

Species	Comments	Locale	Total Hg	Methylated Hg	Source
Harbor seal	Correlated positively with age	Boothbay Harbor, ME	0.520-7.90	12.5-36.6%[b]	Gaskin et al. 1973
Harbor seal		Grand Manan Island (New Brunswick)	1.72-50.9	1.8-10.5%[b]	
Harbor seal	Correlated positively with age	Sable Island	2.91-21.7		Sergeant and Armstrong 1973
Gray seal		Sable Island	0.46-387		
Hooded seal		Magdalen Island	27.2-45.2		
Harp seal		Gulf of St. Lawrence	0.84-10.00		
Harbor porpoise	Correlated positively with age	Bay of Fundy	m[c]: 0.89-18.30 f: 0.55-91.3	7.4-41%[b]	Gaskin et al. 1972
Short-finned pilot whale		Lesser Antilles	19-157	2-17%[b]	Gaskin et al. 1974

[a]Katona et al. 1977.
[b]Inverse correlation between % methylated Hg and total Hg.
[c]m=males; f=females.

methylmercury to other tissues, for example, the brain. Katona and coworkers (1977) discuss research supporting the identification of the biochemical mechanism for mercury de-methylation and storage, perhaps a highly efficient selenium "trap." A one-to-one molar ratio of mercury to selenium has been observed in marine mammal liver tissue and the selenium may aid in binding the mercury to protein molecules (via sulphur bonds), thus preventing the transport of methylmercury.

Documentation of the physiological effects of metal poisoning in marine mammals is scarce. Ingestion of large quantities of methlymercury has caused severe lesions and damage in harp seals (Tessaro and Ronald 1976). Freeman and coworkers (1975) reported that methylmercury, arsenic, cadmium, and selenium altered the "in vitro" biosynthesis of steroid hormones in gray seals. Methylmercury altered the biosynthesis of steroid hormones in an "in vivo" study of harp seals. This could have serious effects on mineral and water regulation, carbohydrate metabolism, and reproduction in contaminated seals.

Petroleum. According to Katona and coworkers (1977) data on the effects of oil contaminants on marine mammals are scarce. Nothing of certainty is known about oil effects on cetaceans. Since all whales surface frequently they are potentially in danger of being exposed to surface oil slicks. Whales that are primarily surface feeders, such as the right whale, sei whale, and (on occasion) the humpback and finback whales could be particularly susceptible to surface oil slicks. It is not known whether these animals would actively avoid oil slicks. The available evidence indicates that petroleum hydrocarbons are not biologically magnified through the food chain. Limited studies of oil effects on seal populations reveal either no significant deleterious effects or inconclusive results (Katona et al. 1977). It is safe to presume that the impact of oil pollution will be most severe in populations that are already suffering from poor health or environmental stress, for example, climatic extremes, high density habitat, strong competition for food and space, and demands of reproduction (Geraci and Smith 1976).

Habitat Disturbance

Habitat disturbance and changes that could influence the abundance and distribution of marine mammals are not well documented. Katona (1977) provides some possible causes and effects. Urbanization and its associated activities (boat traffic and pollution) are detrimental to the occurrence and number of cetaceans in coastal waters. It is difficult, though, to separate the effects of increased shipping from those associated with deteriorating water quality. Areas near port cities tend to have fewer cetaceans than do nearby undeveloped waters, probably due to human activity. Seals are apparently intolerant of human activities at least during the pupping and breeding season. Harbor seals in Maine compete for use of ledges and islands in areas that are valuable to commercial fishing. Fishing efforts and development of coastal shoreline and island property may render certain whelping sites unsuitable. Of the small gray seal breeding colony at Grand Manan, New Brunswick, Canada, Mansfield and Beck (1977) doubt that pup production there will ever build up from a present level of about 15 pups per year to its former level of 200 pups per year, because lobster fishing activity is high during the breeding season. Increased use of islands in

Maine during the summer months may limit the use of these areas by both harbor and gray seals. Entrapment of seals and cetaceans in fishing gear is a present danger and increasing threat.

A summary of data on the reported incidental catch and strandings of cetaceans in Maine waters since 1975 is compiled from Prescott and coworkers (1979) and shown in table 13-9. The major causes of disturbance to cetaceans have been entanglement in fishing gear and collision with boats. Of the 47 reported incidences in the U.S. Atlantic waters, 13 (36%) occured in Maine waters.

Table 13-9. Reported Incidental Catch and Strandings of Cetaceans in Maine Waters Since 1975[a].

Species	#	Location	Date	Fate and Cause
Minke whale	1	Eastport	7/06/76	Dead; possible ship collision
Unidentified	1	Beals Is.	9/15/79	Dead; found entangled in lobster trap gang
Minke whale	2	Mt. Desert Is.	7/78	Dead; reported by fisherman
Harbor porpoise	1	Mt. Desert Is.	6/78	Dead; full-term fetus found in gill net
Minke whale	1	Boothbay	7/07/75	Dead; possible ship collision
Habor porpoise	1	Cranberry Is.	6/04/79	Dead; caught in gill net
Minke whale	1	Bailey's Is.	5/23/78	Alive; damaged gill net
Finback whale	1	Isle Au Haut	11/26/75	Alive; caught in lobstering gear
Harbor porpoise	1	Penobscot Bay	4/15/75	Dead; caught in gill net
Humpback whale	1	Lubec	9/02/79	Alive; trapped in stop seine, released
Unidentified	1	Offshore	6/27/78	Dead; caught in gill net
Right whale	1	Offshore	11/05/76	Dead; cuts and slashes observed on back, reported as right whale
Total	13	36%		
Total US Atlantic	47			

[a] Source: Prescott et al. 1979.

Noise pollution (due to boating, construction, and aircraft passage) could upset the food-finding mechanisms and navigational ability of many cetaceans. Aircraft noise has a documented detrimental effect on seals, causing fright and temporary site desertion (Katona 1977). Offshore oil and gas exploration or pipeline construction could affect cetacean distribution in local areas. These activities generate noise, air and water pollution and physical obstructions. If they are present in areas that are particularly important for feeding, significant disruptions of whale movement or habits could result. Several banks in the Gulf of Maine (Stellwagon Bank, Jeffreys and Columbia Ledges, and Georges Bank) are major feeding grounds for finback whales, humpback whales, right whales and numerous dolphin species. Anticipated OCS oil and gas development activities in the Georges Bank area could affect whales migrating through to Maine waters. It is not known whether these animals or the fish they feed on would simply move to another area or whether population damage would occur.

IMPORTANCE TO HUMANITY

Nearly all the historical sources, especially the older ones, mention the great abundance of whales and seals in the Gulf of Maine, so we know that the abundance and role of marine mammals in New England waters must have been much larger in times past than it is today. Whale and seal harvests once provided an important commercial industry and were a focal point in a way of life for coastal New England residents. Excessive harvest of these animals was the major cause of their decline world wide (see "History of Whaling" below). New England and European hunting activities seriously depleted stocks of whales that might have inhabited coastal Maine. With the cessation of whaling activities in the United States and Canada in 1972, marine mammal populations are no longer locally exploited for commercial yield. However, some European countries still hunt populations that may frequent the Gulf of Maine and Canada allows culling of local populations of gray seals (molted pups).

Marine mammals are also valuable for monitoring levels of pollutants in the marine environment (see "Pollutants" above). Seals in Maine may compete with people for food and habitat use and are definite hosts for parasitic worms, which infect commercially important fish (see "Habitat Disturbance" and "Disease and Parasites" above). The aesthetic value or wilderness experience of viewing marine mammals in the wild is important to residents and tourists alike. Whale sighting excursions out of a number of coastal towns to the nearshore banks are extremely popular and increasing.

Marine mammals also provide extensive opportunities for scientific and educational study in natural history, evolution, and population and community ecology. Nearshore coastal Maine and the approaches to the Bay of Fundy are unique in providing access to several species of marine mammals on a regular basis.

History of Whaling

> "During the 1912 voyage of the whaleship Daisy, Dr. Robert Cashman Murphy, an American Ornithologist, was quoted as saying '...the sounding of this

> sperm whale filled me with astonishment that has increased through the years'. He noted that 'killing a harpooned sperm whale...if you do kill him...may take anywhere from ten minutes to a day or longer'" (Mathews 1968).

Whaling can be dated back as early as 890 A.D. along the coast of Norway. Most noted for whaling during the 12th through 15th centuries were the Basques, who pursued these mammals on a commercial basis for oil and food products (Whale Fishery of New England 1968). In pursuit of the right whale, the Basques ventured farther and farther from their home ports, eventually covering a large portion of the North Atlantic. The "right" whale was so called because it was considered the right whale to catch, due to its slow swimming speed, long baleen, thick blubber, and because it floated when dead (Hill 1975). The French and the Icelanders were also known to have hunted whales during the 12th century, while English whaling was first reported during the 14th century. At that time the whale was declared "a royal fish," and the head and the tail of all whales caught along the English coast were given to the king and queen respectively.

During the early 1600s, large herds of bowhead whales were recorded by explorers in the Arctic Ocean who were seeking a northwest passage to the Orient. These stocks along the groups of islands known as Spitsbergen, north of Norway, were quite valuable because of the bowhead's long baleen and thick blubber, which is almost 2 feet (.6 m) thick. So plentiful were these stocks that when baleen prices were high, it was not uncommon for only the prized baleen to be saved, while the remainder of the whale was discarded. The British sent their first Arctic expedition in 1611 and the Dutch in 1612. By 1636 there were indications of a decline in bowhead stocks around eastern Greenland and by 1720 the Spitsbergen fishery was ended. While the Europeans whaled along Canada's eastern Arctic, American whalers hunted the bowhead in the Bering and Chukchi Seas.

Early explorers of the New England coast found large numbers of whales. The native Indians, using canoes, hunted the whales with stone-headed arrows and spears that were attached to short lines with wooden floats. The Eskimos were also whale hunters in the Arctic waters during this time period. They invented the "toggle" harpoon, which was widely used and later improved upon in 1848 by a New Bedford resident.

During settlement of the New England colonies, whaling in nearby waters began to grow. By 1650, suits over the ownership of dead whales, claims of rival whalers, and laws governing drift whales were known to exist (Katona et al. 1977). Regulations stipulated that the government, the town, and the owner all received one third of every whale taken. By 1662 the church also was given a portion of the take.

The success of the Plymouth colony spurred on other colonies to engage in whaling, among them Salem and Hartford, Connecticut. Hartford had a recognized whaling industry as early as 1647 but did not prosper (Whale Fishery of New England 1968). By 1748 it was believed that whalers may have killed off most of the whales that regularly inhabited the waters around Cape Cod. With decreased numbers of right whales, some of the whalers turned to the humpback, pursuing them on short expeditions from Nantucket and Cape Cod (Katona et al. 1977).

A major portion of Nantucket's heritage centers around whaling, as it fast became the center of whaling in the U.S. It is uncertain exactly when shore whaling first began on Nantucket, though it is known to have taken place before 1672 (Craig 1977) and possibly as early as 1608 (Katona et al. 1977). At first Nantucket's waters were so plentiful with whales that there was no need for offshore whaling. The highest yield of shore whaling seems to have been around 1726, when 86 whales were taken by boats along the shore. The species most likely to have been taken were the right and the humpback whales. However, in 1712 during a strong northerly wind, Christopher Hussey's whale ship was blown out to sea, where it encountered a large herd of sperm whales. It was then that the first sperm whale known to have been taken by an American whaler was brought back into Nantucket.

The sperm whale soon became the most sought after by the people of Nantucket. Hunters were lured by its prized sperm oil, which was considered superior to the oil of baleen whales for such uses as lubricants for watchmaking, fine leather manufacturing, and chronometer operation. The sperm oil also was used as a luminant for domestic lamps and street lights, while byproducts of the sperm oil were used for making soap and ointments as well as for various industrial uses. Also valued was the "whale ivory" (teeth and panbone of the thin lower jaw), which was used for scrimshaw. In addition there was the possible added inducement of ambergris (an infected mass sometimes found in the intestines of the sperm whale), which brought a high price from the perfume industry.

To catch this valuable sperm whale it was necessary for the whalers to venture into the deep sea. A whole new fishery began, which reached its peak by 1847 with New England ships operating all over the world (Hill 1975). Vast improvements were made to the whaling vessels, which would be at sea from 2 to 4 years at a time or until their holds were full to capacity. Around 1730 "try-works" were built on the vessels (instead of on the shore), thus allowing the oil to be boiled and stowed away while the ship was still at sea (<u>Whale Fishery of New England</u> 1968). By 1760 Nantucket was producing more oil than all other American whaling ports combined (Nelson 1971).

With the coming of the American Revolution, Nantucket was the only port to continue whaling. Whaling was a necessity for Nantucket, for it and whaling industries were the basis of Nantucket's economy. Although many whaling ships and men were lost during the Revolution the industry was soon rebuilt and again flourished until the War of 1812. Nantucket was the only American whaling port during this war, also. Still, the two wars and the Great Fire of 1845 took their toll on Nantucket's whalers and with the increased size of the newer ships they were no longer able to clear the sandbar located in Nantucket's port. In 1869 Nantucket sent her last whaling ship, the <u>Oak</u>, out to sea. New Bedford replaced Nantucket as the whaling center of the U.S. It was said that "...the population (there) was divided into three parts, those away on a voyage, those returning, and those getting ready for the next trip" (<u>Whale Fishery of New England</u> 1968). Its first ships were sent out in 1765 and, though greatly affected by the wars, in 1857 the New Bedford fleet numbered 329 and was valued at over $12 million (Whale Fishery of New England 1968).

The so-called "Golden Age" of whaling spanned the years 1825 to 1860. In 1875 the fleet in New Bedford's port had declined to 116, in 1886 to 77, and in 1906 to 24 (Whale Fishery of New England 1968). Rhode Island's two major whaling ports were Newport and Providence. In 1731 an act was passed giving "a bounty of 5 shillings for every barrel of whale oil and one penny a pound for bone" caught by Rhode Island vessels (Katona et al. 1977). A total of 50 ships was owned by Conecticut and Rhode Island in 1775, and Massachusetts owned in excess of 300. New London, Connecticut, became a great whaling port in 1846 and was considered third in importance in New England. Boston, Massachusetts, was known to have 20 whaleships in 1775 and Portsmouth, New Hampshire, had 2 whaling vessels at one time.

About 1810, shore whaling began in Prospect, Maine, with an average catch of 6 or 7 whales per year, primarily humpback (Katona et al. 1977). Between the years of 1835 to 1845 Bath, Bucksport, Portland, and Wiscasset, Maine, each had one whaling vessel operating (Whale Fishery of New England 1968).

After 1895 only Boston, New Bedford, Provincetown, and San Francisco whalers were regularly registerd. In 1903 Boston recorded her last whaleship (Mathews 1968). In 1925 the whaling schooners John R. Manta and Margarett returned to the port of New Bedford, marking the end of the sailing whaleships (Whale Fishery of New England 1968).

The decline in whaling was due to a number of factors, including the development of kerosene and other substitutes for whale products, the opening of the first oil well in Pennsylvania, the rise of the cotton industry in New Bedford around 1850 to 1875, the increased costs of outfitting the ships for longer voyages and the coming of the Civil War, and probably the growing scarcity of whales.

During whaling's "Golden Age" men ventured out in 30-foot boats where "there was always the chance of a fatal accident to someone in the boat, and occasionally the chase took the whole crew so far from the ship that contact was not reestablished. After these battles with the whales, which might have lasted 12 hours or more, came the hard towing of the whale carcass back to the ship and then, in succession, with no intermission, two dangerous and fatiguing jobs," which involved the stripping of blubber and gathering of the oil-bearing parts, along with the crude refining of the oil (Craig 1977). Today's modern whale ships, better known as factory ships, are "capable of reducing a 90-foot blue whale to unrecognizable 'products' in a half-hour" (Hill 1975).

During the 19th century a porpoise (harbor porpoise) fishery existed in the Bay of Fundy and Grand Manan Island. It was believed that the Passamaquoddy and Micmac Indian tribes captured several thousand porpoises yearly. Two to three gallons of oil could be rendered from one porpoise. This oil was marketed for lamps and lubricants. The porpoise fishery also was carried out on an irregular basis throughout New England (Sergeant and Fisher 1957). New fisheries were common during the late 18th century for bottlenose dolphin along Long Island and from Cape May, New Jersey, during the latter part of the 19th century.

The bowhead and right whales have not recovered from the "Golden Age" of whaling and are considered rare in the Western North Atlantic (Katona et al. 1977). Though whaling no longer exists in U.S. waters, Canadians continued to take finback, sei, and minke whales until 1972, when all Canadian stations were closed. Hunting of humpback, blue, fin, and pilot whales has had a profound effect on cetacean populations in Maine. Several of the European countries, such as Iceland, Greenland, and Norway, still hunt whales in the North Atlantic on a non-commercial basis. Japan and Russia account for 80% of the present day catch of both commercial and noncommercial whaling (Craig 1977).

Today whales are used for such products as margarine, lipstick, pet food, tennis racket strings, and automobile wax. Russia diligently pursues the sperm whale for its oil. Japan claims whales are an important source of protein for it's island population, although over 50% of their take is sperm whales, which are considered inedible (Hill 1975). Japan also imports whale meat from other International Whaling Commission (IWC) countries.

Some hunting of harbor porpoises or other small dolphins may still occur sporadically along the eastern Maine coast or adjoining Canadian waters, although this was expressly forbidden by the Marine Mammals Protection Act passed in 1972. Harbor porpoises are still hunted for subsistence in the North Atlantic by Iceland, Greenland, and Norway.

Gray and harbor seals are known to have been hunted by the Indians in New England but the extent of this is not fully known. Both Maine and Massachusetts had bounties on seals (Maine from 1891 to 1905 and from 1937 to 1947, while Massachusetts' bounties were in effect from 1888 to 1908 and from 1919 to 1962; Gilbert et al. 1978) and Canada has had a bounty on gray seals since 1976 and a bounty on harbor seals in all but a few years since 1938. It is believed that although seals were sometimes utilized for their meat and hides most seals were killed to reduce competition for fish. Today there is no direct harvesting of seals in the characterization area but Canadian stocks of gray seals are culled to control local populations (Mansfield and Beck 1977). In addition, seals are sometimes shot by fishermen, who maintain that the seals pirate their fish and foul their nets.

Fossil records and fragmentary bone remains indicate that the walrus was known to have been an occasional visitor to Maine's coastal waters. It is believed that the walrus was once hunted by the Indians in Maine. Figures on its historic population and distribution are uncertain and difficult to establish.

MANAGEMENT

Jurisdiction over the conservation, management, and importation of all marine mammals rests with the Federal Government under the Marine Mammal Protection Act of 1972. This Act sets forth regulations for the taking of marine mammals subject to U.S. jurisdiction and provides enforcement procedures. All New England species are managed by the National Marine Fisheries Service (Department of Commerce). States are free to promulgate regulations regarding management of local stocks providing they satisfy the intent of the Act. In addition, the Act calls for initiation of a cooperative international program. Concurrently, the Act established the Marine Mammal Commission as a major authority responsible for the development of research activities and resource management recommendations. A moratorium exists at present on the taking, killing, or harassment of all marine mammals in U.S. waters except by permit issued by the Secretary of Commerce.

The findings and declaration of policy of the Act are excerpted below:

1. certain species and population stocks of marine mammals are, or may be, in danger of extinction or depletion as a result of man's activities;

2. such species and population stocks should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population. Further measures should be immediately taken to replenish any species or population stock which has already diminished below that population. In particular, efforts would be made to protect the rookeries, mating grounds, and areas of similar significance for each species of marine mammal from the adverse effect of man's actions;

3. there is inadequate knowledge of the ecology and population dynamics of such marine mammals and of the factors which bear upon their ability to reproduce themselves successfully;

4. negotiations would be undertaken immediately to encourage the development of international arrangements for research on, and conservation of, all marine mammals;

5. marine mammals and marine mammal products either

   A. move in interstate commerce, or

   B. affect the balance of marine ecosystems in a manner which is important to other animals and animal products which move in interstate commerce, and that the protection and conservation of marine mammals is therefore necessary to insure the continuing availability of those products which move in interstate commerce; and

6. marine mammals have proven themselves to be resources of great international significance, esthetic and recreational as well as economic, and it is the sense of the Congress that they should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem. Whenever consistent with this primary objective, it should be the goal to obtain an optimum sustainable population keeping in mind that optimum carrying capacity of the habitat.

RESEARCH PRIORITIES

In September, 1979, the Marine Mammal Commission sponsored a workshop to identify and summarize information and research needs for East and Gulf Coast cetaceans and pinnipeds. The participants agreed that insufficient evidence was available to define the status and trends of cetacean and pinniped populations and identified those human activities that may threaten marine mammal species and populations as: incidental take, fishery conflicts (including competition), disturbance/harassment, and habitat degradation/ destruction. The final report on the proceedings and findings of the workshop has recently been released (Prescott et al. 1979).

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Chapter 14
Waterbirds

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Waterbirds include seabirds, shorebirds, wading birds, and waterfowl and with the exception of waterfowl, which are discussed in chapter 15, waterbirds found along the Maine coast are described in this chapter. Approximately 100 species of waterbirds breed, migrate, or winter along the Maine coast. The diversity of waterbirds is related to the variety of waterbird habitats found along the coast, including breeding habitats (coastal islands, lakes, and wetlands), migrating habitats (intertidal mudflats and salt marshes, deepwater tidal rips, protected bays, and highly productive offshore waters), and wintering habitats (ice free estuarine and marine waters and rocky shores).

Waterbirds are an important and conspicuous component of the coastal ecosystem. They are valued mostly for recreation, including waterfowl hunting (common eider), bird watching, and nature study. They are high level consumers in the food webs, and are prone to accumulate toxic substances from their prey that may interfere with reproduction or cause death. People indirectly harm waterbirds by altering the amount and quality of their habitats (i.e., by dredging and filling land, impounding waters, channelizing streams, and developing islands). Directly, waterbirds are killed by hunters, poisoning, or by accident.

The purpose of this chapter is to describe the ecological relationships of waterbirds within the ecosystem of the Maine coast, to summarize the population status of each waterbird group, and to discuss the effects of people on waterbirds and provide information to help mitigate these effects.

Where information is available, the discussion of each group will contain the present status of breeding, wintering, and migrating populations, historical summaries, food and feeding habits, major feeding, roosting, or breeding locations in each region, and factors affecting distribution and abundance. Reviews of human impacts on waterbirds, the importance of waterbirds to society, and management considerations follow the discussion of the waterbird groups, and data gaps and research needs are described. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

DATA SOURCES

The primary data source for breeding seabirds is Maine Coastal Waterbird Colonies 1976-1977 (Korschgen 1979). This source will be referred to hereafter as the coastal waterbird inventory. The list of important seabird nesting islands was obtained from Maine Department of Inland Fisheries and Wildlife (MDIFW) files. These files also contain more recent (1978) information on certain seabird colonies, especially those in Penobscot Bay (region 4), and common eider moulting areas. Data on least terns and piping plovers were acquired from the Maine State Planning Office (Dorr 1976a and 1976b) and unpublished reports on least terns (Lee 1977). Data for coastal heron colonies were taken from the coastal waterbird inventory (Korschgen 1979) and Herons and Their Allies: Atlas of Atlantic Coast Colonies, 1975 and 1976 (Osborn and Custer 1978), while data for inland heron colonies were provided by the Maine State Planning Office (Tyler 1977).

Important feeding, roosting, and staging areas for shorebirds were obtained from published field reports in the Bulletin of the Maine Audubon Society (1946 to 1956), Maine Field Naturalist (1957 to 1967), Maine Field Observer (1956 to 1961), Maine Nature (1969 to 1973), and New Brunswick Naturalist (1970 to 1979). A card file of bird observations organized by the Portland Museum of Natural History and Maine Audubon Society (currently in special collections at the Fogler Library, University of Maine, Orono, ME) was examined for specific details on locations of published and unpublished shorebird sightings. Newsletters from local Audubon chapters also were reviewed for information on sightings of shorebirds. International Shorebird Surveys of Maine (ISS) and unpublished field notes were examined and numerous interviews with coastal residents familiar with shorebirds were conducted. Historical information was extracted from Bent (1921, 1926 ,1927, and 1929), Norton (1923a, 1923b, 1924a, 1924b, 1924c, 1925a, and 1925b), Palmer (1949 and 1962), Stout (1967), and Drury (1973 and 1974). Data for the regional overviews came from Drury (1973 and 1974), Brown et al. (1975), ISS reports (Harrington and Haber 1977; and Harrington 1979), and Maritime Shorebird Survey Reports (Morrison 1976a, 1976b, 1977, and 1978; and Hicklin 1978).

WATERBIRD GROUPS

In this chapter, waterbirds are grouped into four categories based on taxonomic affinity and, to a lesser extent, by feeding habits, as follows:

1. Seabirds. Birds that spend most of their lives at sea or along the adjacent coast and obtain most of their food while flying, swimming, or diving. Representatives of this group include shearwaters, storm petrels, cormorants, gulls, terns, and alcids (table 14-1).

2. Shorebirds. Birds that obtain their food by either probing, pecking, or stalking prey in intertidal habitats, shallow fresh water, marshes, and wet meadows. Representatives of this group include sandpipers, plovers, turnstones, and curlews (table 14-2).

3. Wading birds. Birds that obtain their food by wading and stalking their prey in shallow water. They are relatively long legged, long necked, and light bodied and include herons, egrets, and ibises (table 14-3).

4. Waterfowl. Birds that obtain their food either by diving or dabbling, breed in fresh water, and winter at sea, in estuaries, or open fresh water. This group, which includes ducks, geese, and swans, is discussed in chapter 15. The three waterfowl species discussed with the seabirds in this chapter are grebes, loons, and eider ducks.

Within these groups, birds are further divided according to their seasonal occurrence in Maine as follows:

1. Permanent residents. Species present during all seasons. The term "permanent resident" refers to the species rather than to individual birds. Birds that breed in Maine may not necessarily be the same individuals that winter in Maine (e.g., great black-backed gull, herring gull, common loon, and common eider).

2. Breeding summer residents. Species breeding in Maine that are present only during the breeding season and during migration.

3. Nonbreeding summer residents. Species that breed in the southern hemisphere and spend the winter season in northern waters (Wilson's storm petrel and the shearwaters), and non-breeding individuals of species breeding farther north (subadult and nonbreeding adult gannets, kittiwakes, fulmars, murres, and great cormorants) or to the south (certain herons). Most species in this category are seabirds.

4. Migratory residents. Species present only during the fall or spring migration.

5. Winter residents. Migratory species that winter locally but breed elsewhere (several seabirds and purple sandpipers).

SEABIRDS

Seabirds spend most of their lives far at sea or in the waters along the immediate coast. In Maine, seabirds are represented by loons, grebes, shearwaters, storm petrels, gannets, cormorants, eiders, gulls, terns, jaegers, and alcids. In the characterization area 39 species of seabirds occur regularly (table 14-1) and 18 species are rare visitants (table 14-4). Fourteen species breed in coastal Maine (table 14-1).

Seabirds feed primarly in open water habitats and, to a much lesser extent, in intertidal areas. They are high level consumers, taking a variety of animal prey ranging from zooplankton and shrimp to finfish, and may influence the structure of their prey communities. Seabirds may form feeding groups with members of their own species and with other species of seabirds, and sometimes with marine mammals, finfish, bald eagles, and ospreys. Occasionally seabirds are prey for large falcons, bald eagles (mostly in winter), large finfish, marine mammals, and, of course, hunters.

Table 14-1. Common Seabirds of Coastal Maine. (Species breeding in Coastal Maine are indicated by an asterisk).

Common name	Taxonomic name
Gaviiformes	
* Common loon	Gavia immer
Red-throated loon	Gavia stellata
Podicipediformes	
Pied-billed grebe	Podilymbus podiceps
Red-necked grebe	Podiceps grisegena
Horned grebe	Podiceps auritus
Procellariiformes	
Northern fulmar	Fulmarus glacialis
Greater shearwater	Puffinus gravis
Sooty shearwater	Puffinus griseus
Manx shearwater	Puffinus puffinus
* Leach's storm petrel	Oceanodroma leucorhoa
Wilson's storm petrel	Oceanites oceanicus
Pelecaniformes	
Gannet	Morus bassanus
Great cormorant	Phalacrocorax carbo
* Double-crested cormorant	Phalacrocorax auritus
Anseriformes	
* Common eider	Somateria mollissima
Charadriiformes	
Pomarine jaeger	Stercorarius pomarinus
Parasitic jaeger	Stercorarius parasiticus
Skua	Catharacta skua
Glaucous gull	Larus hyperboreus
Iceland gull	Larus glaucoides
* Great black-backed gull	Larus marinus
* Herring gull	Larus argentatus
Ring-billed gull	Larus delawarensis
Black-headed gull	Larus ridibundus
* Laughing gull	Larus atricilla
Bonaparte's gull	Larus philadelphia
Little gull	Larus minutus
Black-legged kittiwake	Rissa tridactyla
* Common tern	Sterna hirunda
* Arctic tern	Sterna paradisaea
* Roseate tern	Sterna dougallii
* Least tern	Sterna albifrons
Black tern	Chlidonias niger
* Razorbill	Alca torda
Common murre	Uria aalge
Thick-billed murre	Uria lomvia
Dovekie	Palutus alle
* Black guillemot	Cepphus grylle
* Common puffin	Fratercula artica

Table 14-2. Common Shorebirds of Coastal Maine

Common name	Taxonomic name
Semipalmated plover	*Charadrius semipalmatus*
Piping plover	*Charadrius melodus*
Killdeer	*Charadrius vociferus*
American golden plover	*Pluvialis dominica*
Black-bellied plover	*Pluvialis squatarola*
Ruddy turnstone	*Arenaria interpres*
American woodcock	*Philohela minor*
Common snipe	*Capella gallinago*
Long-billed curlew	*Numenius americanus*
Whimbrel	*Numenius phaeopus*
Upland sandpiper	*Bartramia longicauda*
Spotted sandpiper	*Actitis macularia*
Solitary sandpiper	*Tringa solitaria*
Willet	*Catoptrophorus semipalmatus*
Greater yellowlegs	*Tringa melanoleucus*
Lesser yellowlegs	*Tringa flavipes*
Red knot	*Calidris canutus*
Purple sandpiper	*Calidris maritima*
Pectoral sandpiper	*Calidris melanotos*
White-rumped sandpiper	*Calidris fuscicollis*
Baird's sandpiper	*Calidris bairdii*
Least sandpiper	*Calidris minutilla*
Dunlin	*Calidris alpina*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Stilt sandpiper	*Micropalama himantopus*
Semipalmated sandpiper	*Calidris pusillus*
Western sandpiper	*Calidris mauri*
Buff-breasted sandpiper	*Tryngites subruficollis*
Marbled godwit	*Limosa fedoa*
Hudsonian godwit	*Limosa haemastica*
Ruff	*Philomachus pugnax*
Sanderling	*Calidris alba*
Red phalarope	*Phalaropus fulicarius*
Wilson's phalarope	*Steganopus tricolor*
Northern phalarope	*Lobipes lobatus*

Table 14-3. Common Wading Birds of Coastal Maine.

Common name	Taxonomic name
Great blue heron	*Ardea herodias*
Green heron	*Butorides striatus*
Little blue heron	*Florida caerulea*
Cattle egret	*Bubulcus ibis*
Great egret	*Casmerodius albus*
Snowy egret	*Egretta thula*
Louisiana heron	*Hydranassa tricolor*
Black-crowned night heron	*Nycticorax nycticorax*
Yellow-crowned night heron	*N. violacea*
Least bittern	*Ixobrychus exilis*
American bittern	*Botaurus lentiginosus*
Glossy ibis	*Plegadis falcinellus*

Table 14-4. Seabirds Rare in Coastal Maine.

Common name	Taxonomic name
Arctic loon	Gavia arctica
Western grebe	Aechmophorous occidentalis
Eared grebe	Podiceps caspicus
Yellow-nosed albatross	Diomedea chlororhynchos
Cory's shearwater	Puffinus diomedea
British storm petrel	Hydrobates pelagicus
Magnificient frigatebird	Fregata magnificens
Long-tailed jaeger	Stercorarius longicaudus
Ivory gull	Pagophila eburnea
Lesser black-backed gull	Larus fuscus
Mew gull	Larus canus
Franklin's gull	Larus pipixcan
Sabine's gull	Xema sabini
Forster's tern	Sterna forsteri
Royal tern	Thalasseus maximus
Caspian tern	Hydroprogne caspia
Sooty tern	Sterna fuscata
Black skimmer	Rynchops niger

The coastal waters have been divided into the following four general physical zones to describe the distribution and abundance of seabirds:

1. Estuarine. Deepwater tidal habitats and adjacent wetlands which are usually semienclosed by land but have access to open ocean (Cowardin et al. 1979).
2. Inshore Marine. Marine waters within 6 miles (10 km) of land.
3. Offshore Marine. Marine waters beyond 6 miles extending out to the 300-foot (91-m) depth contour.
4. Pelagic. Deep marine waters beyond the 300-foot depth contour.

The distribution and abundance of seabirds in each of these 4 zones and in inland lakes are presented in table 14-5. Most species show a preference for one or two zones but may feed in all of them.

These zones are not always distinct. For example, inshore waters overlap offshore and pelagic waters if the 300-foot depth contour occurs within 6 miles of shore. This situation is common in region 6 and as a result many pelagic and offshore species can be seen in inshore and estuarine waters such as Machias, Passamaquoddy, and Cobscook Bays.

Table 14-5. Seasonal Occurrence and Relative Abundance of Seabirds Regularly Occurring in Various Habitats in the Characterization Area

Seasonal occurrence and common name	Inland lakes	Estu-arine	In-shore	Off-shore	Pelagic
Breeding residents					
Common loon	2	2	2	1	0
Common eider	0	2	2	2	0
Greater black-backed gull	2	2	2	2	2
Herring gull	2	2	2	2	2
Razorbill	0	0	2	2	2
Black guillemot	0	1	2	2	0
Leach's storm petrel	0	0	0	1	2
Double-crested cormorant	2	2	2	1	0
Laughing gull	0	2	2	1	0
Common tern	1	2	2	2	0
Roseate tern	0	1	1	1	0
Arctic tern	0	1	2	2	1
Least tern	0	2	2	1	0
Common puffin	0	0	1	1	1
Nonbreeding summer residents					
Wilson's storm petrel	0	0	0	2	2
Greater shearwater	0	0	1	2	2
Sooty Shearwater	0	0	0	1	2
Manx Shearwater	0	0	0	1	1
Fulmar	0	0	0	1	1
Common Murre	0	0	1	1	0
Migratory residents					
Gannet	0	0	1	2	2
Pomarine jaeger	0	0	0	1	2
Parasitic jaeger	0	0	0	1	2
Skua	0	0	0	0	1
Ring-billed gull	1	2	2	1	0
Black-headed gull	0	0	0	0	0
Bonaparte's gull	1	2	2	2	0
Little gull	0	0	0	0	0
Black tern	1	2	2	0	0
Winter residents					
Common loon	2	2	2	1	0
Common eider	0	2	2	2	0
Greater black-backed gull	2	2	2	2	2
Herring gull	2	2	2	2	2
Razorbill	0	0	2	2	2
Black guillemot	0	2	2	2	0
Red-throated loon	0	0	1	0	0
Red-necked grebe	0	0	1	1	0

(Continued)

Table 14-5. (Concluded)

Seasonal occurrence and common name	Inland lakes	Estu-arine	In-shore	Off-shore	Pelagic
Winter residents (cont.)					
Horned grebe	0	2	2	2	0
Northern fulmar	0	0	1	2	2
Great cormorant	0	1	2	2	0
Glaucous gull	0	1	1	1	1
Iceland gull	0	1	1	1	1
Black-legged kittiwake	0	1	1	2	2
Common murre	0	0	1	1	2
Thick-billed murre	0	0	1	1	2
Dovekie	0	0	1	2	2

0=rare or absent; 1=uncommon; 2=abundant or common.

Historical Trends

During the 19th century, populations of most species of seabirds declined because of human exploitation and disturbance of nesting colonies. Hunting, egg-collecting, and disturbance of nesting islands by grazing sheep, introduced pets, lumbering, and construction led to the elimination of breeding populations of double-crested cormorants, great black-backed gulls, eiders, puffins, and black guillemots along the Maine coast by the 1870s (Norton 1923b; Drury 1973). Between 1870 and 1900, terns, laughing gulls, and herring gulls were slaughtered to provide feathers for the millinery industry. Many of the herring gull colonies on inshore islands were abandoned during the 1890s and the only known large colony remaining was on No Mans Land Island (region 4; Norton 1923b). Leach's storm petrels and some species of terns survived in moderate numbers during this period (Drury 1973 and 1974).

State laws protecting seabirds were enacted as early as 1901 and enforcement was financially supported by the American Ornithologist's Union and the National Association of Audubon Societies. Most species increased markedly as a result of protection. After 1900, numbers of common eiders, black guillemots, and puffins increased steadily until recently, when their numbers have begun leveling off (figure 14-1). Herring gulls increased from about 11,000 pairs in 1900 to over 40,000 pairs in the 1920s. Since then populations have fluctuated between 20,000 and 36,000 pairs (figure 14-1). Cormorants and great black-backed gulls recovered more slowly than other species. They were presumably scarce prior to 1930, after which they have increased markedly (figure 14-2).

Common terns increased from a low of around 1000 pairs in 1900 to nearly 9000 pairs in 1930. Arctic terns, on the other hand, remained fairly stable throughout the period (figure 14-2). Since the 1950s numbers of both common and arctic terns have decreased, presumably as a result of increases in numbers of herring and black-backed gulls which prey on eggs and chicks and also steal food from adult birds that are on their way to feed nestlings. Roseate terns, laughing gulls, puffins, and razorbills are also frequent victims of gull predation (Nettleship 1972). Gulls also may take over preferred nesting sites. Puffin and razorbill populations are currently stable, but all three species of terns and the laughing gulls are declining in Maine.

Although numbers of Leach's petrels seemed to be unaffected by exploitation in the last century, their numbers have declined since 1900 because of habitat disturbance on their nesting islands (e.g., construction, logging, and grazing).

Present Status of Seabirds

Breeding species. Fourteen species of seabirds breed along the Maine coast (table 14-5). The common loon breeds on inland lakes and least terns nest on sand beaches on the mainland. All other species nest in colonies on offshore islands. The characterization area has a total of 321 nesting colonies of seabirds and supports the largest breeding populations of arctic terns, double-crested cormorants, Leach's storm petrels, common eiders, razorbills, common puffins, and black guillemots in eastern U.S. waters.

Region 4 has the most seabird colonies (117), followed in decreasing order by regions 3 (60); 1 (50); 5 (39); 6 (34); and 2 (21). A complete list of nesting colonies and their locations are presented in the appendix table 1. The most important nesting islands are shown on atlas map 4.

The common eider is the most abundant nesting seabird along the Maine coast (table 14-6). Over 22,000 pairs nest on 240 islands. Eiders nest in all 6 regions of the characterization area but 41% are found in region 4. Leach's storm petrels are nearly as abundant as the common eider but are much more localized in distribution. Petrels nest in 17 colonies in regions 3 to 6 but nearly 95% of the population breeds in only 4 colonies in region 5 (table 14-6).

The herring gull ranks third in abundance (16,695 pairs). It breeds in all 6 regions but is most abundant (36%) in region 4. The double-crested cormorant (14,549 pairs), great black-backed gull (6575 pairs), and black guillemot (2665 pairs) are also found in all six regions, and like the herring gull and common eider are most abundant in region 4 (table 14-6).

Of the large-bodied terns, the common and arctic terns are about equally abundant (1898 and 1640 pairs respectively), whereas the roseate tern is much less abundant (55 pairs). These terns nest on 29 coastal islands in either mixed species (3 islands) or single-species colonies (26 islands). More than one-half of the breeding population of arctic terns south of Labrador nests on

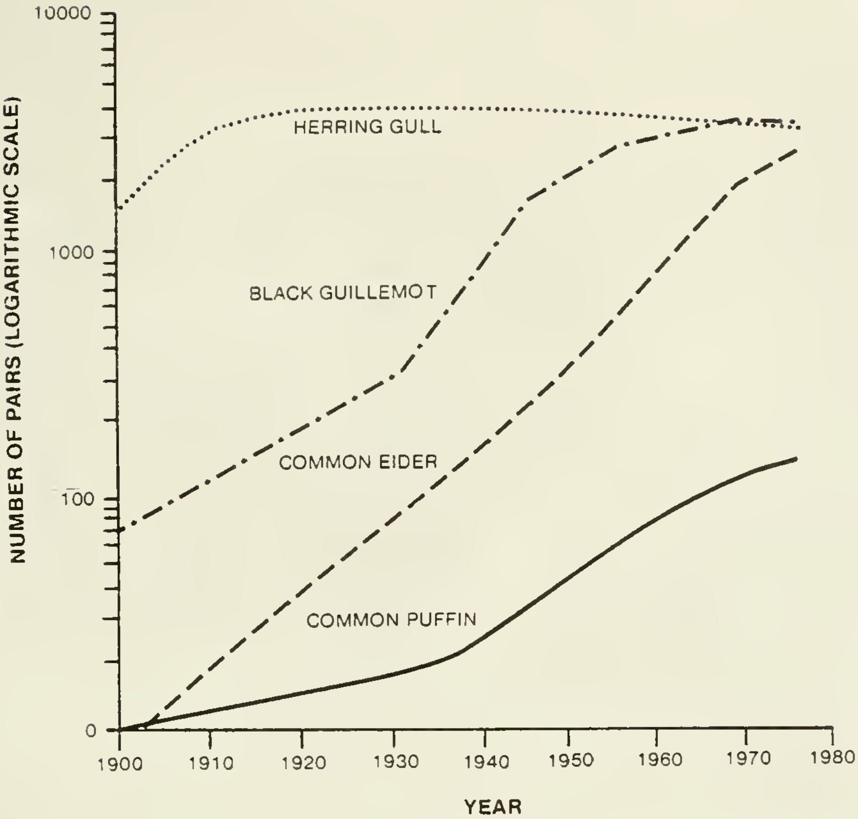

Figure 14-1. Trends in populations of nesting herring gull, eider, black guillemot, and puffin in Maine since 1900 (adapted from Drury 1973 and Korschgen 1979).

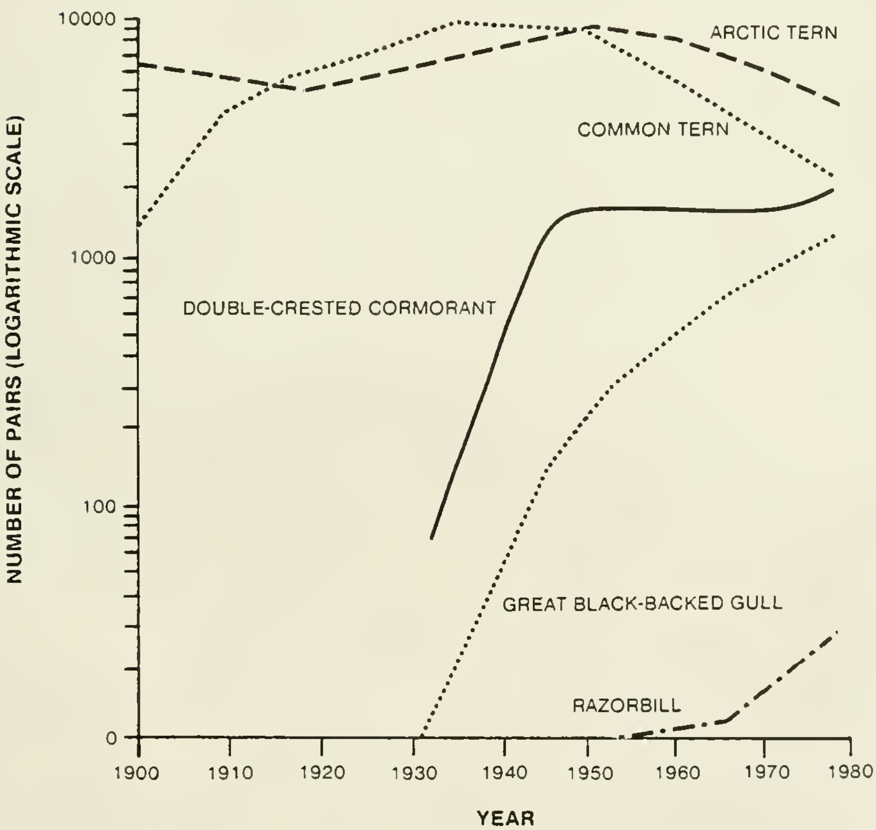

Figure 14-2. Trends in populations of nesting great black-backed gull, double-crested cormorant, arctic and common tern, and razorbill auk in Maine since 1900 (adapted from Drury 1973 and Korschgen 1979).

Table 14-6. Estimated Numbers (percentage contribution to the total in parentheses) of Nesting Pairs of Seabirds (breeding summer residents) in Each Region of the Characterization Area in 1977.[a]

Species	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total characterization area
Common eider	1836 (8)	425 (2)	4420 (20)	9047 (41)	2855 (13)	3683 (17)	22,266
Leach's storm petrel	-	-	77 (<1)	966 (5)	18,053 (94)	35 (<1)	19,131
Herring gull	3182 (19)	689 (4)	1025 (6)	6044 (36)	2373 (14)	3382 (20)	16,695
Double-crested cormorant	1638 (11)	891 (6)	2065 (14)	5162 (35)	3714 (26)	1079 (7)	14,549
Great black-backed gull	864 (13)	644 (10)	642 (10)	1601 (24)	1717 (26)	1107 (17)	6575
Black guillemot	20 (1)	33 (1)	260 (10)	1158 (43)	830 (31)	364 (14)	2665
Common tern	213 (11)	350 (18)	225 (12)	390 (21)	700 (37)	20 (1)	1898
Arctic tern	-	350 (21)	10 (1)	505 (31)	700 (43)	75 (5)	1640
Laughing gull	-	-	32 (14)	49 (21)	150 (65)	-	231
Common puffin	-	-	-	125 (100)	-	-	125
Roseate tern	-	35 (64)	-	-	20 (36)	-	55
Razorbill	-	-	-	15 (60)	-	10 (40)	25
Least tern	-	7 (100)	-	-	-	-	7

[a]Korschgen 1979.

Petit Manan (region 5), Matinicus Island (region 4), and Machias Seal Island (region 6, ownership disputed by U.S.; Drury 1973).

Laughing gull populations have never been high in Maine, comprising less than 250 pairs in 1977. This scarcity is perhaps due to the abundance of herring gulls, which displace laughing gulls from preferred nesting locations (Nisbet 1973). More importantly, laughing gulls are at the northern end of their range in Maine. Laughing gulls are always found nesting in association with either common or arctic terns.

The common puffin breeds in one colony at Matinicus Rock in region 4 (125 pairs). It also nests in proximity to the Maine coast at Machias Seal Island in New Brunswick (1100 pairs estimated; personal communication from R. Newell, Acadia University, Department of Biology, Wolfville, Nova Scotia, Canada; February, 1979). The National Audubon Society, in cooperation with Cornell University, is attempting to reestablish the puffin on Eastern Egg Rock (region 3), formerly the southernmost breeding colony. They are using transplanted, hand-reared young from Newfoundland and decoys to attract potential breeders.

The razorbill (25 pairs) and the least tern (20 pairs) are the least abundant breeding seabirds along the Maine coast. The razorbill nests on two islands (one each in regions 4 and 6) and the least tern nests on two sand beaches on the mainland (Popham Beach and Sprague River Beach in region 2).

Common loons breed on inland lakes and ponds in all six regions, although they are more abundant in regions 5 and 6 than in regions 1 to 3. A higher level of human activity in regions 1 to 3 is presumed responsible for the lower populations there (personal communicatione from B. Christenson, University of Maine, School of Forest Resources, Orono, ME; March, 1979).

Although seabirds nest on 321 islands in the characterization area the majority of nesting birds of most species are found on far fewer islands. Based on criteria jointly developed by the U.S. Fish and Wildlife Service (FWS), the University of Maine, and the Maine Department of Inland Fisheries and Wildlife, 127 islands have been designated "significant" breeding islands. These islands contain single species colonies that comprise 1% or more of the total breeding population of that species, or mixed species colonies whose aggregate percentage is 1% or more of the total breeding population of all species combined. These 127 islands contain over 90% of the total coastal Maine breeding populations of Leach's storm petrels, laughing gulls, common terns, arctic terns, razorbills, and puffins, and over 80% of cormorants, eiders, and black guillemots (table 14-7). Approximately half of the breeding populations of herring and black-backed gulls also nest on these islands. Region 4 has the largest number of significant breeding islands (46), followed in decreasing order by regions 3 (20), 5(19), 6 (17), 1(17), and 2(8). These islands are indicated by an asterisk in appendix table 1, and all 127 islands are plotted on atlas map 4. A region by region account of the most important islands follows.

Region 1 has 17 major nesting islands. The five most important islands are Outer Green, Stockman, Grass Ledge, White Bull Island, and Ram Island (Casco Bay).

Table 14-7. Percentage of Total Nesting Pairs of Seabirds Breeding on 126 Major Islands in Coastal Maine During 1977[a]

Common name	Regions						Total for all regions
	1	2	3	4	5	6	
Leach's storm petrel	-	-	<1	5	94	<1	99
Double-crested cormorant	11	5	12	30	23	6	87
Common eider	7	1	16	36	12	15	87
Great black-backed gull	5	6	6	14	17	10	58
Herring gull	8	2	2	21	8	12	53
Laughing gull	-	-	14	21	65	-	100
Common tern	10	17	10	16	33	10	96
Arctic tern	-	21	1	31	43	5	100
Roseate tern	-	44	-	-	25	-	69
Razorbill	-	-	-	60	-	40	100
Black guillemot	+	1	5	40	30	13	89
Common puffin	-	-	-	100	-	-	100
TOTAL ISLANDS	17	8	20	46	19	17	127

[a]Korschgen 1979.

Region 2 has 8 major nesting islands. The 5 most important are North Sugarloaf Island, White Island, Heron Island, Pumpkin Island, and Pond Island. North Sugarloaf supports a large mixed colony of arctic, roseate, and common terns, and once supported laughing gulls. It is particularly vulnerable to human disturbance because it is located near the mainland in a high-use recreation area (Popham Beach State Park). The only least terns nesting in the characterization area nest in this region at Popham Beach and along Sprague River Beach. Further details on these two locations can be found in Dorr (1976a) and Lee (1977). The Maine Audubon Society monitors populations in these two colonies.

Region 3 has 20 major nesting islands. The five most important include Killick Stone Island, The Brothers Island, Western Egg Rock, Metinic Green Island, and Metinic Island. Currently region 3 supports fewer seabirds than in the past. For example, this region formerly supported the southernmost breeding colony of common puffins (Eastern Egg Rock) and several additional colonies of Leach's storm petrels. It is now the southernmost breeding area in Maine for Leach's storm petrels.

Region 4 has 46 major seabird islands. Among the regions it has the greatest number of nesting islands for all species except common, roseate, and least terns, and the greatest number of nesting pairs for all species except terns, great black-backed and laughing gulls, and Leach's storm petrels. The most important nesting island in Maine, Matinicus Rock, is in region 4. It has the only common puffin colony in Maine owned by the Federal Government and has one of the only two razorbill colonies in the coastal zone, as well as large numbers of arctic terns, laughing gulls, guillemots, and some Leach's storm petrels.

The largest numbers of cormorants, eiders, herring gulls, and black guillemots nest in region 4 (35%, 41%, 36%, and 43% of total State populations respectively). The 5 most important colonies are on Matinicus Rock, Wooden Ball Island, Thrumcap Island, Seal Island, and No Mans Land Island.

Region 5 has 19 major seabird breeding islands. This region is most important for Leach's storm petrels, great black-backed gulls, laughing gulls, common terns, and arctic terns. The 5 most important breeding islands include Petit Manan Island, Great Duck Island, Little Duck Island, Schoodic Island, and Ship Island. Great Duck Island has the largest petrel colony south of Newfoundland, and Petit Manan Island and Machias Seal Island (in region 6) are the most important areas south of Newfoundland for breeding arctic terns.

Region 6 has 17 major seabird islands. The 5 most important islands are Old Man Island (east), Libby Island, Browney Island, The Brothers, and Ballast Island. Old Man Island has one of the only two U.S. razorbill colonies in the coastal zone. The region is very important for arctic terns, common puffins, and razorbills (Machias Seal Island) and contains Maine's largest eider colony (Libby Island).

Most of the important colonies are located west of Cutler (few islands are located along the coast east of Cutler). To the east, Cobscook Bay supports small numbers of eiders, cormorants, herring gulls, and great black-backed gulls. Two important seabird nesting islands in Cobscook Bay are Goose Island and Spectacle Island.

Nonbreeding summer residents. Nonbreeding summer resident birds breed in the southern hemisphere during our winters and spend their winter in the North Atlantic. The most common species are the sooty, manx, and greater shearwaters, Wilson's storm petrel, and some southern skuas (table 14-5). The northern fulmar has been observed more frequently in recent years. These species are generally found in offshore and pelagic waters but wander inshore during periods of extended fog or east-southeast winds. They are more common in regions 5 and 6 and their abundance increases with distance from land. Their seasonal occurrence in the Gulf of Maine (based primarily on Bluenose Ferry sightings) was recently reviewed by Finch et al. (1978).

Winter residents. Seventeen species of seabirds are found along the Maine coast in winter (table 14-5). Eleven species are found primarily in inshore and estuarine waters and six species inhabit offshore and pelagic waters.

The herring gull, common eider, and great black-backed gulls are the most abundant winter residents. They are found in inshore and estuarine waters throughout the coastal area. Horned grebes and great cormorants are somewhat less abundant than the above species. Horned grebes are found throughout the coastal zone, usually as single birds or in small groups of less than 10. Occasionally they will be found in flocks as large as 300 during the fall and spring migration.

Great cormorants are found throughout inshore areas and around inner and outer islands. They occupy habitat similar to that used by double-crested cormorants during the summer but they do not extend as far into estuaries. They arrive in mid-September and depart in April and early May. A few (mostly subadults) may spend the summer on outer islands or ledges.

The red-throated loon and red-necked grebe are uncommon winter residents along the Maine coast. Red-throated loons are usually found in harbors, coves, and outer estuaries, whereas red-necked grebes frequent outer headlands and islands.

Glaucous and iceland gulls are found in association with herring gulls and great black-backed gulls in coastal bays and estuaries, and around garbage dumps, fish processing plants, and raw sewage outlets. Individuals are scattered throughout the coastal zone but the greatest numbers (as many as 100) are found near Lubec and Eastport (region 6).

Among the offshore and pelagic species the kittiwake and fulmar are the most abundant and occur in flocks numbering in the thousands. They are most abundant in the waters of regions 5 and 6. In Passamaquoddy Bay kittiwakes have occured in flocks of over 10,000, and more than 48,000 have been seen in the eastern approaches to the Bay of Fundy. The dovekie may occur in rafts (groups of birds in the water) numbering in the thousands, especially in the Quoddy region (off the southern end of Grand Manan Island and the Cutler headlands). Inshore they are generally found in small groups numbering less than 20.

Common and thick-billed murres are uncommon in the coastal zone. They are usually found offshore and around outer islands of regions 5 and 6 but small numbers are occasionally found inshore near harbors, inner islands, and coastal headlands.

Migratory residents. Six species of seabirds are found along the Maine coast only during migration (table 14-5). Most of these are more common in fall than in spring and may remain in coastal waters for several months. They are locally common near upwellings and tidal rips. Bonaparte's gull is the most abundant migrant. Typically, concentrations of a few hundred are found in the outer and middle portions of estuaries, such as Back Bay in Portland (region 1), Raccoon Cove in Lamoine (region 5), and Mason's Bay near Jonesboro (region 6). Several thousand can be found in Cobscook Bay (region 6) and tens of thousands in Passamaquoddy Bay near Eastport. Concentrations of several hundred are often found roosting on inland ponds and lakes along the coast.

The ring-billed gull is a common migrant, with flocks of a few hundred occurring in the upper portions of coastal estuaries, such as the Pleasant (region 6), Jordan (region 5), Union (region 4), Damariscotta (region 3), and Kennebec Rivers (region 2) and Back Bay in Portland (region 1). It is also very abundant (a few thousand) in Passamaquoddy Bay (region 6) in August and September. Ring-billed gulls have increased in recent years, both as nonbreeding summer residents and as winter residents.

The gannet is a common migrant in both spring and fall. It is most abundant offshore but is commonly observed from coastal headlands during periods of easterly and southeasterly winds.

Other less common migrants include the skua, parasitic jaeger, and pomarine jaeger. They are offshore and pelagic species that only enter the characterization area occasionally.

Reproduction

With the exception of the common loon all species of seabirds that breed along the coast nest in colonies. Colonial nesting in birds is thought to evolve when the following conditions prevail: (1) relative freedom from predation, particularly ground predators, such as mammals and reptiles; (2) food sources are concentrated and patchy in distribution, so that many individuals must feed together and territorial defense of food supplies is not possible; and (3) a shortage of preferred nesting sites exists, so that many individuals must nest together. Colonial nesting in turn benefits individual pairs in defending against predators. The major predators in seabird colonies are other birds, primarily gulls, crows, and ravens. Colony members can sometimes drive these predators away by attacking together.

Nesting in colonies also helps birds locate food. Since food sources are often widely distributed in marine systems, birds that are successful in locating food are followed from the colony to the source by other birds.

As a group, seabirds have small clutches (1 to 5 eggs), relatively protracted development periods for nestlings, and delayed breeding in adults (up to 5 years for petrels). Low predation rates and patchy, often distant food supplies, make it adaptive to invest more time and energy in a few eggs and young rather than trying to raise a large brood (which might die of exposure or starve). Even among the seabirds these reproductive characteristics vary. Petrels lay one egg, nest in protected burrows, and delay breeding until the adults are 5 years old. Petrels feed far offshore and spend much time searching for food. They may remain away from the nest for up to 2 days. The young develop very slowly to accommodate the scarce food supplies. They may remain in the nest for over 60 days.

In contrast, gulls, terns, eiders, cormorants, and guillemots lay two or more eggs, usually in exposed nests, and breed at an earlier age (2 to 4 years). The nesting islands are closer to inshore and estuarine waters, which are more productive than offshore waters. Consequently the young develop more rapidly than do petrels.

Along the Maine coast, seabirds nest from mid-April (great black-backed gulls) through late October (Leach's storm petrel). Each species has a peak laying period that may vary up to three weeks, depending on weather conditions and disturbances (figure 14-3). Also, birds in the southwestern regions (1 and 2) begin nesting earlier than birds in the northeastern regions (5 and 6). The laying peaks for several species overlap. Great black-backed gulls, herring gulls, cormorants, and eiders start nesting in late April and early May, while terns, alcids, Leach's storm petrel, and laughing gulls initiate nesting in late May and early June.

In late summer large rafts of moulting eiders form at several locations along the coast. At the same time large concentrations of herring gulls and great black-backed gulls occur in nearshore estuarine feeding and roosting areas. These concentrations occur in August after the young birds have fledged.

The largest postbreeding concentrations occur in the eastern portion of region 6 (Passamaquoddy Bay, south Lubec, and Machias Bay), as this area is adjacent to large gull colonies in the vicinity of Grand Manan Island (i.e., 16,000 pairs on Kent Island, New Brunswick).

Feeding Habits

Among seabirds each group of species uses a characteristic feeding method (table 14-8). Birds that feed at or near the surface do so by dipping (bird in flight drops to the surface to snatch prey), pattering (bird in flight uses its feet to disturb the surface, which attracts prey), surface seizing (bird grabs prey while sitting on the surface), scavenging (bird feeds on offal, cannery waste, or at sewage outflows), pursuit diving (bird dives from the surface to chase prey in the upper depths), and shallow plunging (bird plunges from the air into the water to a shallow depth to seize prey). Birds that feed in deeper waters practice pursuit plunging (bird plunges into the water while flying and then swims or 'flies' underwater pursuing its prey), deep plunging (bird dives deeper than shallow plunging), pursuit diving, and bottom feeding (bird usually dives from surface to gather benthic invertebrates and bottom dwellers). Jaegers, gulls, and terns often steal food from other seabirds (Hatch 1970 and 1975).

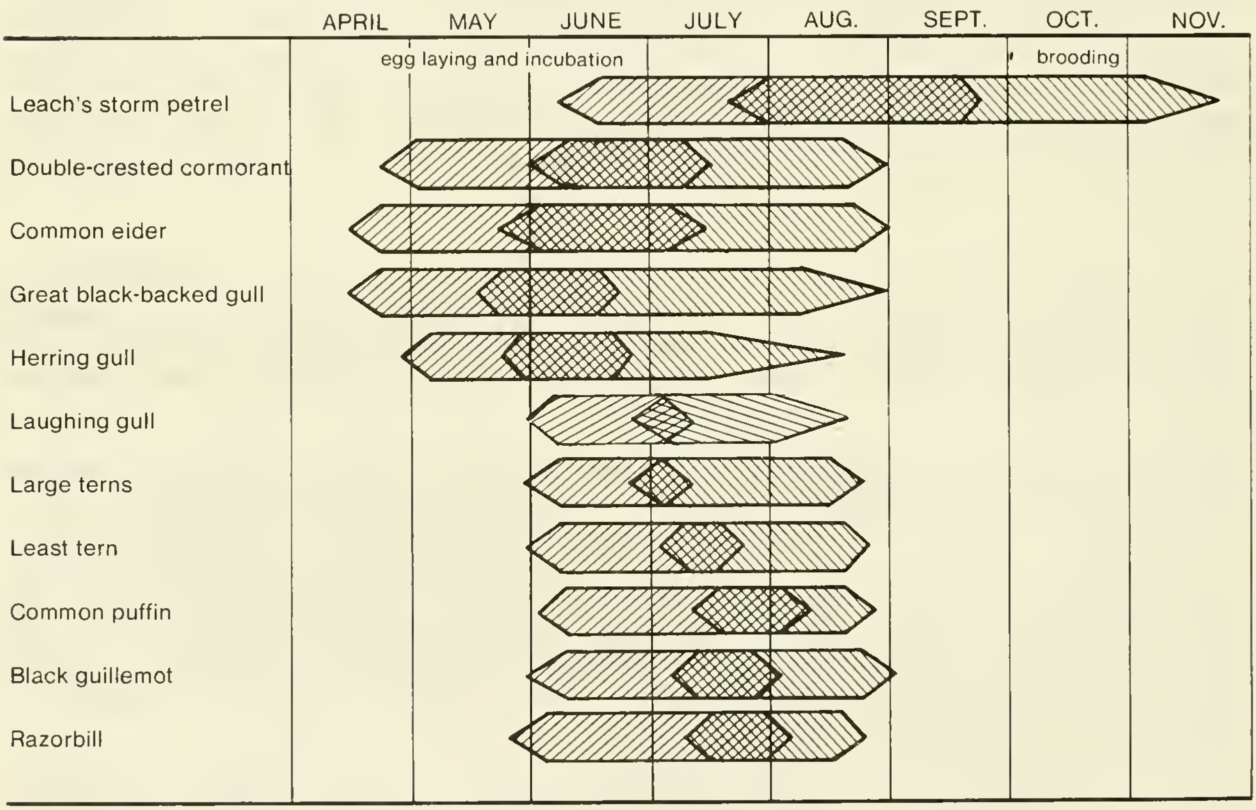

Figure 14-3. Timing of egg laying, incubation, and breeding of seabirds in coastal Maine (crosshatch represents overlap).

Table 14-8. Feeding Habits of Seabirds Regularly Occurring in the Characterization Area [a]

Major feeding habitat and common names	Surface and near surface: Dipping	Surface and near surface: Pattering	Surface and near surface: Surface seizing	Surface and near surface: Scavenging	Surface and near surface: Pursuit diving	Surface and near surface: Shallow plunging	Deeper water: Pursuit plunging	Deeper water: Deep plunging	Deeper water: Pursuit diving	Deeper water: Bottom	Piracy	Terrestrial
Estuarine-inshore												
Common loon	0[b]	0	0	0	0	0	0	0	2	1	0	0
Red-throated loon	0	0	0	0	0	0	0	0	2	1	0	0
Red-necked grebe	0	0	0	0	0	0	0	0	2	1	0	0
Horned grebe	0	0	0	0	0	0	0	0	2	1	0	0
Pied-billed grebe	0	0	0	0	0	0	0	0	2	1	0	0
Double-crested cormorant	0	0	0	0	0	0	0	0	2	1	0	0
Common eider	0	0	0	0	0	0	0	0	1	2	0	0
Glaucous gull	1	0	1	2	0	1	0	0	2	1	1	0
Iceland gull	1	2	1	2	0	1	0	0	0	0	1	0
Great black-backed gull	1	0	1	2	0	1	0	0	0	0	1	1
Herring gull	1	0	1	2	0	1	0	0	0	0	1	1
Ring-billed gull	1	0	1	1	0	1	0	0	0	0	1	0
Black-headed gull	1	0	1	1	0	1	0	0	0	0	1	0
Laughing gull	1	0	1	1	0	1	0	0	0	0	1	0
Bonaparte's gull	2	0	1	1	0	1	0	0	0	0	1	0
Little gull	2	0	1	0	0	1	0	0	0	0	2	0
Common tern	1	0	0	0	0	2	0	0	0	0	2	0
Roseate tern	1	0	0	0	0	2	0	0	0	0	2	0
Least tern	1	0	0	0	0	2	0	0	0	0	0	0
Black tern	1	0	0	0	0	2	0	0	0	0	0	0
Inshore-Offshore												
Great comorant	0	0	0	0	0	0	0	0	2	1	0	0
Arctic tern	2	0	0	0	0	2	0	0	0	0	0	0
Dovekie	0	0	0	0	0	0	0	0	2	0	0	0
Black guillemot	0	0	0	0	0	0	0	0	1	2	0	0

(Continued)

Table 14-8. (Concluded)

Major feeding habitat and common names	Surface and near surface						Deeper water				Piracy	Terrestrial
	Dipping	Pattering	Surface seizing	Scavenging	Pursuit diving	Shallow plunging	Pursuit plunging	Deep plunging	Pursuit diving	Bottom		
Offshore-Pelagic												
Northern fulmar	0	0	2	1	0	0	0	0	0	0	0	0
Greater shearwater	0	0	1	0	1	1	2	0	0	0	0	0
Sooty shearwater	0	0	1	0	1	1	2	0	0	0	0	0
Manx shearwater	0	0	1	0	1	0	2	0	0	0	0	0
Leach's storm petrel	1	1	1	0	0	0	0	0	0	0	0	0
Wilson's storm petrel	0	2	1	0	0	0	0	0	0	0	0	0
Gannet	0	0	0	0	0	0	0	2	0	0	0	0
Pomarine jaeger	1	0	0	0	0	1	0	0	0	0	2	0
Parasitic jaeger	1	0	0	0	0	1	0	0	0	0	2	0
Skua	1	0	0	0	0	1	0	0	0	0	2	0
Black-legged kittiwake	2	0	1	0	0	1	0	0	0	0	0	0
Razorbill	0	0	0	0	1	0	0	0	2	0	0	0
Common murre	0	0	0	0	1	0	0	0	2	0	0	0
Thick-billed murre	0	0	0	0	1	0	0	0	2	0	0	0
Common puffin	0	0	0	0	1	0	0	0	2	0	0	0

[a]Adapted from Ashmole 1971.
[b]0=infrequently or never used; 1=frequently used; 2=primary feeding habit.

Knowledge of feeding methods is important in evaluating potential environmental impacts. For example, in the event of an oil spill birds that spend most of their time on the water and dive for their food are more susceptible to feather oiling than are birds that feed on the wing. Creation of impoundments for tidal power may reduce the amount of intertidal mudflats and adversely affect species that feed there.

As a group seabirds feed primarily on fish and crustaceans but also consume cephalopods, other invertebrates, offal and garbage (table 14-9). Birds that feed by dipping, pattering, and surface seizing eat crustaceans, other invertebrates, small fish, and cephalopods. Birds that feed by pursuit diving, shallow plunging, and deep plunging eat fish and, to a lesser extent, large invertebrates. Birds that feed on the bottom take benthic invertebrates and some fish.

Along the Maine coast food may be abundant overall but is usually concentrated in specific habitats and may be dispersed in patches. Some species of seabirds (e.g., terns) are better adapted for finding these patches of food and their activity in turn attracts other species. As a result, feeding associations between seabird species are common. They usually avoid competing with each other by using different feeding methods and by selecting different prey.

Seabirds may also feed with pods of marine mammals (whales, dolphins, and seals) and sometimes with large fish (such as tuna and mackerel) according to Baltz and Morejohn (1976). Fishermen may use groups of feeding terns, gulls, and shearwaters (as well as marine mammals) to locate schools of fish.

Natural Factors Affecting Abundance

The factors that control the abundance of seabirds along the Maine coast are not entirely known. The following paragraphs summarize the ways in which predation, food supply, and nesting habits might affect abundance.

Predation. Except during the breeding season, seabirds are relatively free from natural predators. Small islands afford the safest breeding locations because they are relatively free of mammalian predators. Gulls (herring and great black-backed), ravens, crows, and great horned owls may prey heavily on the eggs and flightless young. Islands with introduced mammalian predators or islands that occasionally are attached to the mainland by ice make poor seabird nesting areas.

Food supply. The effects of limited food supply are difficult to quantify in offshore areas, where food supplies usually are widely scattered. In Massachusetts a positive correlation exists between the annual herring harvest and tern nesting success (Nisbet 1973). An increase in garbage dumps resulted in higher survival of herring and great black-backed gulls and largely accounted for their population explosion in Maine and elsewhere in New England (Drury and Kadlec 1974). The large flocks of Bonaparte's, herring, and great black-backed gulls, and northern phalaropes (see "Shorebirds" below) found in Passamaquoddy Bay in late summer occur where marine upwelling areas and tidal rips concentrate foods such as euphausiid shrimp.

Table 14-9. Food Types of Seabirds Regularly Occurring in the Characterization Area

Major feeding habitats and common names	Fish	Cephalopods	Crustaceans	Other invertebrates	Garbage and offal
Estuaries-Inshore					
Common loon	2	0	0	0	0
Red-throated loon	2	0	0	0	0
Red-necked grebe	0	0	2	0	0
Horned grebe	0	0	2	2	0
Pied-billed grebe	0	0	0	2	0
Double-crested cormorant	2	1	0	1	0
Common eider	0	1	0	2	0
Glaucous gull	0	1	0	0	2
Iceland gull	0	1	0	0	2
Great black-backed gull	0	1	0	0	2
Herring gull	0	1	0	0	2
Ring-billed gull	0	1	0	0	1
Black-headed gull	0	1	1	0	0
Laughing gull	2	1	1	0	1
Bonaparte's gull	0	1	1	0	1
Little gull	2	1	1	0	0
Common tern	2	1	0	1	1
Roseate tern	2	1	0	1	1
Least tern	2	0	0	0	0
Black tern	2	0	0	1	0
Onshore-Offshore					
Great comorant	2	1	0	1	0
Arctic tern	2	1	0	1	1
Dovekie	1	0	2	1	0
Black guillemot	2	1	2	0	0
Offshore-Pelagic					
Northern fulmar	0	0	2	0	2
Greater shearwater	2	2	2	0	0
Sooty shearwater	2	2	2	0	0
Manx shearwater	2	0	0	0	0
Leach's storm petrel	0	1	2	2	0
Wilson's storm petrel	1	2	2	2	0
Gannet	2	2	0	0	0
Pomarine jaeger	2	1	1	1	1
Parasitic jaeger	2	1	1	1	1
Skua	0	1	0	0	1
Black-legged kittiwake	2	1	2	1	0
Razorbill	2	1	0	1	0

(Continued)

Table 14-9. (Concluded)

Major feeding habitats and common names	Fish	Cephalopods	Crustaceans	Other invertebrates	Garbage and offal
Common murre	2	1	0	1	0
Thick-billed murre	2	1	0	1	0
Common puffin	2	0	0	0	0

0=negligible or infrequently used; 1=frequently used; 2=preferred food.

Birds that feed on the wing, such as terns and petrels, have difficulty feeding during periods of bad weather (Dunn 1973). Rough seas may also prevent diving species from feeding. Many common murres have perished after prolonged periods of bad weather in Alaska (Sealy 1973).

Nesting habits. Along the Maine coast nesting habitat may be limiting for Leach's storm petrel, least terns, and common loons. Petrels nest on islands in underground burrows that they themselves excavate. Excavation is easier in the duff under spruce-fir forests than in the sod on treeless islands. Several islands formerly used by nesting petrels have been cleared of timber and burned, or grazed by sheep, resulting in the development of thick, impenetrable sod. These islands are now uninhabitated or have very small breeding colonies [i.e., Wooden Ball, Little Green and Large Green Islands (region 4), Libby Island and the Brothers Island (region 6), and 14 others summarized by Drury (1973)].

Least terns prefer to nest on sand beaches. The few that are present in Maine are found primarily on the mainland (region 4), where predation and human disturbance are high. They have never been abundant in Maine.

Because of the large number of islands along coastal Maine, the availability of nesting habitat should be adequate for most of the other species of seabirds. Apparently arctic, common, and roseate terns, laughing gulls, and possibly puffins and razorbills, require islands free of nesting herring and great black-backed gulls for successful nesting. For example, most of the larger tern and laughing gull colonies in New England have been taken over by herring and black-backed gulls (Nisbet 1973). In Maine many of the successful tern and alcid colonies are found on islands where lighthouse keepers controlled herring gull numbers (Drury 1973). Young puffins and razorbills are also frequent victims of gull predation. If gull-free islands are required by these species of seabirds, then adequate nesting habitat may be lacking.

SHOREBIRDS

Shorebirds are a closely related group of species (order Charadriiformes, suborder Charadrii) that are represented in Maine by sandpipers, plovers, turnstones, godwits, curlews, dowitchers, and phalaropes. Thirty-three species of shorebirds commonly occur along the Maine coast (table 14-2). Seven additional species visit occasionally in very low numbers. The Maine coast is most important as a feeding and resting area for migrating shorebirds, but six species (piping plover, spotted sandpiper and four upland species) breed along the coast and one species (purple sandpiper) is a winter resident (table 14-10). Of the six breeding species the killdeer, snipe, woodcock, and upland sandpiper are primarily found in upland habitats and are discussed in chapter 16, "Terrestrial Birds."

Shorebirds are found in most marine, estuarine, and palustrine habitats ranging from deepwater marine to estuarine intertidal emergent wetland (saltmarsh). Most species have specialized feeding and roosting habitats (tables 14-11 and 14-12 respectively). The most important feeding habitats are estuarine and marine intertidal mudflats, and the most important roosting habitats are sand and gravel beaches or spits, and nearshore ledges. Shorebirds may also roost on salt pannes in estuarine intertidal emergent wetlands, in fields, golf courses, on tops of buildings, or on rocky ledges.

Shorebirds feed largely on marine and estuarine invertebrates in the intertidal zone and may help supress the abundance of many prey species. They consume a substantial amount of the secondary production of the intertidal system and, because of their transient nature, represent an important energy loss from these systems. Shorebirds, in turn, serve as prey for certain falcons (including the endangered peregrine), accipiters, and marsh hawks.

Shorebirds are now of little direct economic importance, although in the past they were hunted and sold as food in many urban centers and used in the millinery trade. They have high aesthetic and recreational values (bird watching).

Shorebirds should be given special consideration by management authorities because large numbers of these birds depend on coastal habitats for feeding and resting during their long migration from the Arctic breeding grounds to South American wintering areas (Morrison 1977). In addition, they often concentrate in relatively small areas, a practice which can make them susceptible to habitat disturbance and certain environmental contaminants. To date, migratory shorebirds generally have been neglected by decisionmakers who plan coastal developments. They are given only modest consideration in environmental impact statements and in oil-spill cleanup plans.

Table 14-10. Resident Status and Relative Abundance of the Shorebirds of Coastal Maine.

Resident status and species	Relative abundance			
	Spring	Summer	Fall	Winter
Breeding residents				
Piping plover	1	1	0	0
Spotted sandpiper	2	2	2	0
Wintering residents				
Purple sandpiper	2	0	2	1
Migratory residents				
Semipalmated plover	2	2	2	0
American golden plover	0	0	1	0
Black-bellied plover	2	2	2	0
Ruddy turnstone	2	2	2	0
Whimbrel	0	1	1	0
Solitary sandpiper	2	2	2	0
Willet	1	1	1	0
Greater yellowlegs	2	2	2	0
Lesser yellowlegs	1	2	2	0
Red knot	0	1	1	0
Least sandpiper	2	2	2	0
White-rumped sandpiper	0	1	1	0
Dunlin	1	0	2	0
Pectoral sandpiper	1	1	2	0
Short-billed dowitcher	2	2	2	0
Stilt sandpiper	0	1	1	0
Semipalmated sandpiper	2	2	2	0
Marbled godwit	0	0	0	0
Hudsonian godwit	0	1	1	0
Sanderling	1	2	2	0
Rare visitors				
Baird's sandpiper	0	0	0	0
Long-billed dowitcher	0	0	0	0
Western sandpiper	0	0	0	0
Buff-breasted sandpiper	0	0	0	0
Ruff	0	0	0	0
Wilson's phalarope	0	0	0	0

0 = rare or absent; 1 = occasional or uncommon; 2 = common

Table 14-11. Major Feeding Areas of Shorebirds of Coastal Maine.

Species	Mud flats	Sand and gravel beaches	Estuarine intertidal emergent marsh	Riverine system	Marine and estuarine rocky shore	Ter-rest-rial
Semipalmated plover	2	2	1	1	1	0
Piping plover	0	2	0	0	0	0
American golden plover	1	0	0	1	0	2
Black-bellied plover	2	2	1	0	1	0
Ruddy turnstone	1	2	0	0	2	0
Long-billed curlew	2	2	2	0	0	0
Whimbrel	2	2	2	0	0	2
Spotted sandpiper	1	2	2	2	2	2
Solitary sandpiper	1	1	2	2	0	1
Willet	2	2	2	0	0	1
Greater yellowlegs	2	2	2	2	0	1
Lesser yellowlegs	2	2	2	2	0	0
Red knot	2	2	0	0	0	0
Purple sandpiper	1	2	0	0	2	0
Least sandpiper	2	2	2	2	2	0
White-rumped sandpiper	1	2	0	0	0	1
Dunlin	2	2	1	0	1	0
Pectoral sandpiper	2	1	2	2	0	2
Short-billed dowitcher	2	0	2	1	0	1
Stilt sandpiper	2	0	2	0	0	0
Semipalmated sandpiper	2	1	2	1	0	0
Western sandpiper	2	2	2	0	0	0
Buff-breasted sandpiper	0	0	0	0	0	2
Marbled godwit	0	1	2	0	0	0
Hudsonian godwit	0	0	2	0	0	2
Ruff	0	0	1	0	0	1
Sanderling	1	1	0	0	1	0
Wilson's phalarope	1	0	2	0	0	0
Baird's sandpiper	1	1	0	0	0	1
Killdeer	1	0	2	2	0	2

0=rarely or never used; 1=frequently used; 2=preferred.

Table 14-12. Roosting Habitat Types of the Shorebirds of Coastal Maine.

Species	Sand & gravel	Cobble beaches	Sand & Gravel spits	Rocky shores	Rocky ledges	Estuarine intertidal emergent marsh	Pastures barrens & wet fields
Semipalmated plover	2	2	2	2	2	0	0
Piping plover	2	0	2	0	0	0	0
Killdeer	0	0	0	0	0	2	2
American golden plover	1	1	1	0	0	0	2
Black-bellied plover	2	2	2	0	2	2	0
Ruddy turnstone	1	1	2	2	2	2	0
Whimbrel	0	0	0	0	0	1	2
Spotted sandpiper	2	2	2	2	2	1	0
Solitary sandpiper	0	0	0	0	0	1	1
Willet	0	0	0	0	0	2	0
Greater yellowlegs	1	1	2	0	2	2	1
Lesser yellowlegs	1	1	2	0	2	2	1
Red knot	2	1	2	0	1	0	0
Purple sandpiper	0	0	0	2	2	0	0
Pectoral sandpiper	1	0	1	0	0	1	2
White-rumped sandpiper	2	2	2	1	1	0	0
Baird's sandpiper	0	0	0	0	0	0	2
Least sandpiper	1	1	1	2	2	2	1
Dunlin	2	2	2	2	1	0	1
Short-billed dowitcher	1	1	2	1	2	2	1
Stilt sandpiper	0	0	0	0	0	2	0
Semipalmated sandpiper	2	1	2	2	2	1	1
Western sandpiper	2	1	2	0	0	2	0
Buff-breasted sandpiper	0	0	0	0	0	0	2
Marbled godwit	1	0	1	0	0	2	0
Hudsonian godwit	0	0	0	0	0	2	0

(Continued)

Table 14-12. (Concluded)

Species	Sand & gravel	Cobble beaches	Sand & gravel spits	Rocky shores	Rocky ledges	Estuarine intertidal emergent marsh	Pastures barrens & wet fields
Ruff	0	0	0	0	0	1	0
Sanderling	2	1	2	1	1	0	0
Wilson's phalarope	1	0	0	0	0	2	0

0=rarely or never used; 1=frequently used; 2=preferred.

Historical Trends

Although accurate historical records of shorebird numbers are scarce, several accounts indicate they were very abundant from colonial times until the 1870s. About that time market hunters were faced with declining waterfowl populations and turned to shorebirds. At the same time some species (red knot and white-rumped sandpiper) were being hunted on their wintering grounds in Argentina. By the 1890s and early 1900s many species of shorebirds became scarce (Norton, quoted in Palmer 1949 and Cooke 1915). The eskimo curlew, golden plover, whimbrel, and long-billed curlew suffered the greatest losses. The eskimo curlew was particularly susceptible to hunting and remains on the verge of extinction.

Laws protecting shorebirds were enacted during the late 1800s and early 1900s. In 1900 the Lacey Act outlawed interstate transportation of hunted birds. In 1918 most of the small sandpipers and certain of the larger plovers, curlews, and godwits, came under full protection of the Migratory Bird Treaty Act. Hunting seasons on plovers and yellowlegs were allowed until 1927. Since that time most species have made remarkable recoveries although they have probably not recovered their pre-1870 population levels. Loss or deterioration of habitat may prevent a full recovery.

Present Status of Shorebirds

Breeding summer residents. The piping plover and spotted sandpiper are the two species of shorebirds breeding along the Maine coast that are discussed in this chapter. The willet breeds in the Scarboro Marshes just outside the characterization area southwest of region 1. Four upland species are discussed in chapter 16, "Terrestrial Birds."

The piping plover nests in loose colonies on the upper portions of sand beaches. There are six known nesting areas in Maine, two of which (Popham Beach and Sprague River Beach in region 2) are in the characterization area (atlas map 4). In 1976 these two colonies contained four and eight nesting pairs respectively (Dorr 1976b). In addition, piping plovers are reported each year in appropriate breeding habitat in Reid State Park (region 2), but no nests have been reported.

Piping plovers return to Maine from southern wintering areas in early April. Eggs are usually laid in early May but nesting and renesting occurs throughout the month. The eggs (3 or 4) are incubated for 27 days. Although the young are capable of leaving the nest and feeding themselves almost immediately after hatching, they remain under parental attention for at least 6 weeks. They depart from Maine in mid- to late August.

Populations of piping plovers have been declining along the east coast over the last few decades and the species has been placed on the National Audubon Society's Blue List for New England (Arbib 1978). Increased recreational use of beaches by bathers, off road vehicles, fishermen, and pets disturb breeding colonies and reduce nesting success. Opening private beaches to the general public will certainly result in additional disturbances to piping plover breeding areas.

In contrast to the specialized breeding habitat required by the piping plover, the spotted sandpiper nests in a wide variety of coastal and inland habitats, usually as solitary pairs. They nest along rocky shores, in estuarine emergent wetlands, on small islands, and along the shores of inland lakes and streams. Spotted sandpipers are very common in Maine and are not currently threatened by human activities.

Spotted sandpipers usually migrate singly or in small groups and arrive on the Maine coast in late April and early May. Eggs (3 to 4) are laid in mid- to late May and hatch in mid-June. The young leave the nest the same day they hatch and are capable of feeding themselves but are under parental care for about 6 weeks. Spotted sandpipers leave the Maine coast by mid-September for southern wintering grounds.

Winter residents. The purple sandpiper is the only species of shorebird that regularly winters along the coast of Maine. A few individuals or small groups of dunlins, sanderlings, or ruddy turnstones may winter along the coast, especially in southwestern Maine (regions 1 and 2).

Eastern Maine (regions 4 through 6) and adjacent New Brunswick support one of the largest known wintering populations of purple sandpipers in North America. Small numbers begin to arrive along the outer islands and rocky coastline in late July and August but most arrive in October and November. They remain along the Maine coast until April or early May.

Purple sandpipers are generally found in rocky intertidal areas along exposed coastlines. Most of the wintering areas known to be important for purple sandpipers are along the mainland (atlas map 4). Offshore islands also are used but their overall importance is unknown. Purple sandpipers also may be found on sand and gravel bars where they feed on amphipods, mussels, and barnacles. Flocks of less than 100 are most common, although occasionally as many as 500 to 1000 may be seen.

Migratory residents. The greatest numbers of shorebirds and shorebird species are found along the Maine coast during migration. Some 20 species occur regularly in Maine during either the spring or fall migration and another six species are occasional or rare visitors (table 14-10; figure 14-4).

The northern phalarope is the most abundant species of migrant shorebird, although it is not widely distributed in inshore waters along the coast. The waters in the mouth of Passamaquoddy Bay near Eastport (region 6) support an estimated one-half to 2 million phalaropes annually, which may constitute the largest concentration in the North Atlantic (Morrison 1977). Over 1 million birds also have been observed near Mount Desert Rock (region 4; Finch et al. 1978) and in the waters southwest of Grand Manan, New Brunswick. Phalaropes congregate in areas where tidal upwellings concentrate foods such as euphausiid shrimp.

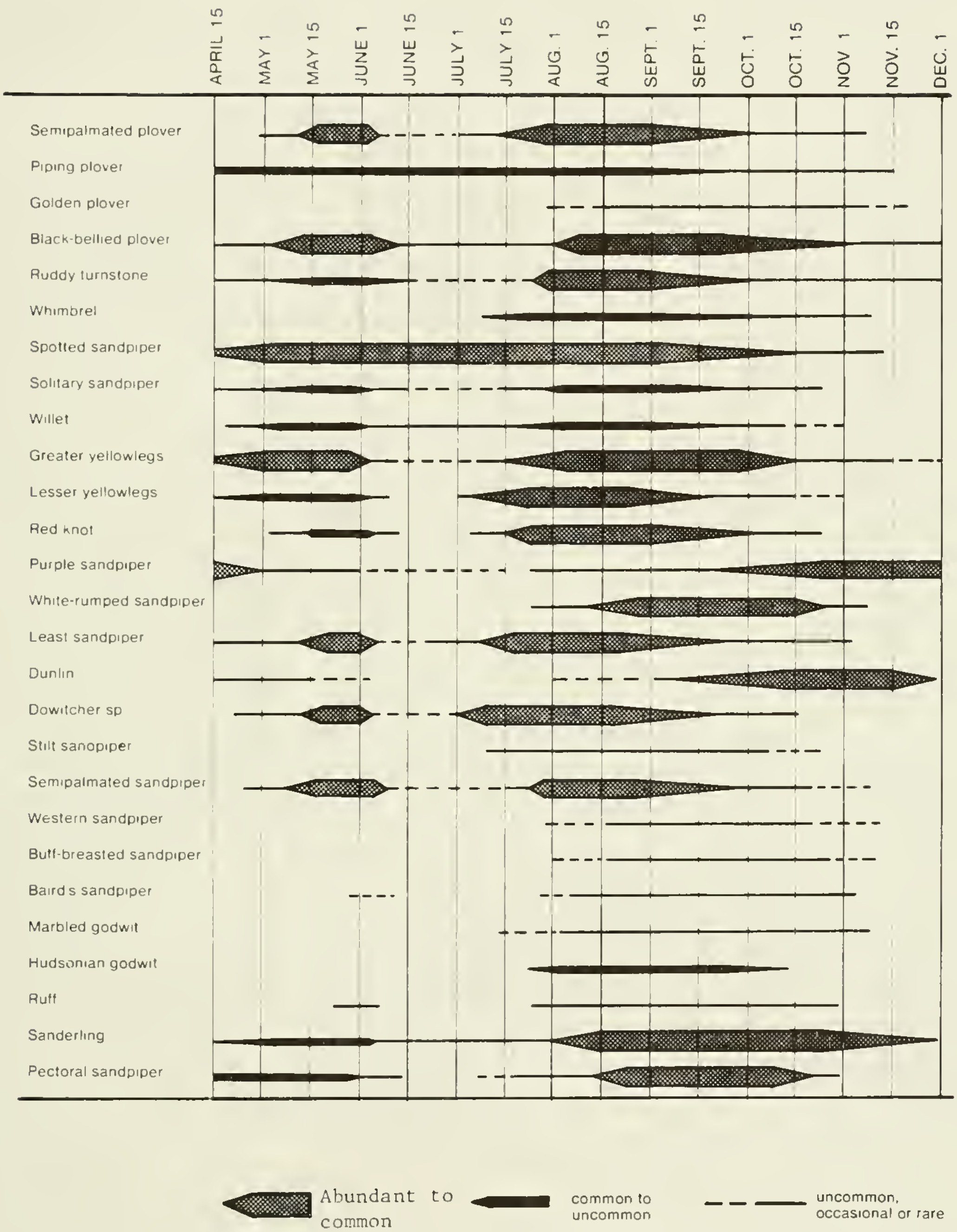

Figure 14-4. Relative abundance and migration of the migratory shorebirds of coastal Maine from April through November. Band width reflects relative abundance for individual species only. (adapted from Morrison 1976a, McNeil and Burton 1973, Palmer 1949, and Gobeil 1963).

The semipalmated sandpiper is also abundant along the Maine coast. Between 300,000 and 500,000 birds pass through the characterization area each year, which constitutes 6% to 10% of the total population migrating along the eastern U.S. (Spaans 1979). Tens of thousands of semipalmated plovers, short-billed dowitchers, black-bellied plovers, and ruddy turnstones also use the Maine coast during migration.

The Maine coast is more important to migrating shorebirds during the fall than during the spring. This is because most species follow an elliptical migration route, moving south along the east coast of the U.S. in the fall and returning through the central plains States in the spring.

The "fall" migration is actually a summer and fall migration, beginning in July and extending through November. The earliest migrants are the short-billed dowitcher, lesser yellowlegs, and least sandpiper, which begin arriving the first week of July. Semipalmated sandpipers, semipalmated plovers, whimbrels, sanderlings, red knots, and greater yellowlegs follow in mid-July. The ruddy turnstone and hudsonian and marbled godwits arrive in late July or early August, and the black-bellied plover and white-rumped sandpiper arrive in early to mid-August. The greatest numbers of birds are usually present between 25 July and 25 August, although the timing may vary up to a week or ten days, depending on weather conditions.

For most species of shorebirds, the adults and juveniles migrate at different times in the summer-fall migration. The adults leave the breeding grounds before the young are capable of sustained flight, and the juveniles follow 3 to 4 weeks later. This produces two "peaks" in the numbers of migrants (table 14-13). Exceptions to this are the short-billed dowitcher, which has three peaks (comprised of adult males, adult females, and juveniles), and the dunlin and purple sandpipers, which have a single peak in October or November.

The spring migration period is much shorter than the fall, beginning in mid-April and extending through early June. The greatest numbers of birds are present between mid-May and the first week of June and all species have only one peak.

The importance of the Maine coast to migrating shorebirds stems from the abundance of feeding and roosting habitats. Commonly used feeding areas include mudflats, salt marshes, sand and gravel beaches, mussel bars, and blueberry fields and bogs, while major roosting habitats are gravel and sand beaches, salt marshes, rocky shores, fields, and pastures. Each species has preferred feeding and roosting habitats (tables 14-11 and 14-12), and the importance of a region to a particular species depends on the abundance of its preferred habitats in that region. In general, intertidal mudflats, sandflats, bogs, and blueberry barrens are more common in regions 5 and 6, while sand and gravel beaches and salt marshes are more common in regions 1, 2, and 3.

Specific areas known to be used consistently by large numbers of migrating shorebirds are listed by regions in the appendix table 2 and are plotted on atlas map 4. This list is not complete since information is not available on much of the coast.

Table 14-13. Major Fall Migration Periods of the Shorebirds of Coastal Maine[a].

Species	Adults mo/day	Juveniles mo/day
Semipalmated plover	7/25 - 8/22	8/25 - 9/15
Black-bellied plover	8/10 - 9/10	9/15 -10/06
Ruddy turnstone	7/25 - 8/25	8/25 - 9/15
Greater yellowlegs	8/15 - 9/10	9/25 -10/20
Lesser yellowlegs	7/20 - 8/15	9/01 - 9/15
Red knot	7/20 - 8/20	8/25 - 9/15
White-rumped sandpiper	8/10 - 9/10	10/10 -11/10
Least sandpiper	7/15 - 8/20	8/25 - 9/15
Short-billed dowitcher	7/10 - 8/15	8/10 - 8/25
Semipalmated sandpiper	7/20 - 8/20	8/20 - 9/15

[a]Modified from Morrison 1976a.

Region 1 contains 12 feeding areas and 6 roosting sites. Greatest concentrations of birds and bird species are usually found at Back Cove (Portland), Presumpscot River flats (Portland), Fore River (South Portland), Middle Bay (Brunswick), and Maquoit Bay (Brunswick). Although shorebird concentration areas are poorly documented in region 1, especially west of Mackworth Point, MDIFW is conducting systematic waterbird surveys (including shorebirds) of the Casco Bay region every two weeks from September, 1979, to October, 1980.

Region 2 has 10 major feeding areas and 5 roosting areas. Major feeding areas include the tidal flats along the Kennebec River, Spirit Pond (Phippsburg), Popham Beach, Sprague River Beach, Reid State Park, Hermit Island Flats (Phippsburg), New Meadows River (West Bath), and Winnagance Creek (South Bath). Roosting areas are generally poorly known for this region. The largest roosting area (5000+ birds) known is on Morse River Beach at Small Point.

The two piping plover breeding colonies of the characterization area are located in region 2 at Popham Beach and Sprague River Beach.

Region 3 is characterized by rocky headlands and rock bound islands with relatively few intertidal mudflats and salt marshes. There are 14 feeding areas and 3 roosting areas. The mudflats along the St. George River in Thomaston, the intertidal flats at Spruce Head (St. George) and the intertidal flats and saltmarshes along the Weskeag River (South Thomaston), are the major shorebird areas. Up to 12,000 semipalmated sandpipers and 1000 semipalmated plovers have been observed along the St. George River. The region is also important for ruddy turnstones and purple sandpipers.

Region 4 is a large region with 13 important feeding areas and 3 major roosting areas. Shorebird areas in this region are poorly documented. The most important areas (based on historic accounts) are Rockland Harbor, Brookline, and the Bagaduce River estuary. Because of its large number of islands this region supports large flocks of wintering purple sandpipers, migrating ruddy turnstones and least sandpipers, and breeding spotted sandpipers. The Penobscot River valley is an important inland migration corridor for spotted sandpipers and killdeer. In addition, many least sandpipers migrate along the shores of the Penobscot.

Region 5 has 33 major feeding areas and 14 important roosting sites (areas of more than 1000 birds). The number of roosting areas is probably underestimated. The coastal zone east of Mt. Desert Island (Trenton Bay to Perry; region 6) is probably the most important fall migratory stopover area in eastern U.S. for semipalmated sandpipers, semipalmated plovers, white-rumped sandpipers, and whimbrels. It is also very important for short-billed dowitchers, black-bellied plovers, and ruddy turnstones.

The largest known semipalmated sandpiper and semipalmated plover roost in the eastern U.S. is located in Wards Cove (east Carrying Place Cove on Ripley Neck), Harrington (region 5). More than 40,000 semipalmatd sandpipers and 2400 semipalmated plovers have been reported from this location. The extensive flats along the Pleasant and Harrington Rivers, Mill Creek, Flat Bay, Back Bay, and Narraguagus Bay (Harrington-Milbridge area) are also important feeding areas for the above species, as well as for short-billed dowitchers, greater and lesser yellowlegs, and black-bellied plovers. The intertidal flats in Steuben, Dyer Bay, Sullivan, and Sorrento are important feeding areas for semipalmated plovers, black-bellied plovers, red knots, and yellowlegs. Petit Manan Point is a regular stopover area for whimbrels, red knots, and godwits. The large mussel and barnacle populations on the Bar Harbor gravel bar attract an abundance of turnstones (up to 600). Many small sandpipers and plovers roost on offshore ledges and small islands (i.e., Dry Ledges in Harrington).

Region 6 has 36 major feeding areas and 40 roosting sites. Large concentrations of semipalmated sandpipers (more than 50,000 birds) have been observed at Half-Moon and Carrying Place Coves in Eastport, the Lubec Narrows in south Lubec, and Machias Bay. The most important known roosting areas in this region are Sprague Neck and the mouth of Holmes Stream (both in Holmes Bay, Cutler), four locations on the Lubec flats (South Lubec and Campobello Island), Johnson's Cove Beach (Eastport), and Pleasant Point (Perry).

Role of Shorebirds in the Ecosystem

Shorebirds feed primarily on amphipods and oligochaete worms, which in turn feed on detritus. Mudflats that are heavily used by shorebirds have high numbers of these detritovores and low amounts of detritus (personal communication from M. J. Risk, McMaster University, Hamilton, Ontario, Canada. May 1979; and Yeo 1978). Migratory shorebirds convert much of their food into fat, which provides energy for the long flights to South American wintering grounds. As a result this energy is lost from the local estuarine environment. The magnitude of this loss and the effect on the estuarine environment have not been determined. Studies in nearby Nova Scotia have shown that populations of preferred prey (*Corophium volutator*, a small amphipod) can be measurably reduced where shorebirds concentrate in large numbers. The greatest concentrations of shorebirds are on the last mudflats to be covered by the rising tide, and the first flats open after high tide.

WADING BIRDS

Wading birds include the herons, egrets, ibises, and bitterns, (order Ciconiiformes). They have relatively long legs and necks and small bodies. Six species of wading birds breed in coastal Maine, and six others are nonbreeding summer residents or visitants (table 14-14). None are regular winter residents. They feed in shallow water in marine and estuarine intertidal areas and palustrine, riverine, and lacustrine systems. Wading birds feed on a variety of prey including reptiles, fish, insects, other invertebrates, birds, small mammals, and some plant material. Because wading birds are top level consumers, biocides tend to accumulate in their tissues. For this reason, wading birds could serve as indicators of levels of environmental contamination.

Historical Perspective

Like seabirds and shorebirds, wading birds were hunted for food, for bait, for sport, and for their feathers (the millinery industry) during the 1800s. In addition, many nesting colonies were disturbed or destroyed by vandals. Early reports (summarized by Palmer 1949) suggest that wading birds declined in Knox County (region 4) between 1820 and 1851, in western Maine between 1885 and

Table 14-14. Resident Status and Relative Abundance of Wading Birds in Coastal Maine for Regions 1 to 3, and 4 to 6.

Resident status and species	Relative abundance			
	Breeding		Nonbreeding	
	1 to 3	4 to 6	1 to 3	4 to 6
Breeding residents				
Great blue heron (*Ardea herodias*)	2	2		
Green heron (*Butorides striatus*)	2	2		
Least bittern (*Ixobrychus exilis*)	1	0		
American bittern (*Botaurus lentiginosus*)	1	2		
Black-crowned night heron (*Nycticorax nycticorax*)	1	1		
Snowy egret (Egretta thula)	1	0	2	2
Nonbreeding residents				
Little blue heron (*Florida caerulea*)			1	0
Cattle egret (*Bubulcus ibis*)			1	1
Great egret (*Casmerodeus albus*)			1	0
Louisiana heron (*Hydranassa tricolor*)			1	0
Yellow-crowned night heron (*N. violocea*)			1	0
Glossy ibis (*Plegadis falcinellus*)			1	0

0=rare or absent; 1=uncommon; 2=common.

1908 (Brewster 1924), and in Casco Bay (region 1) between 1880 and 1900 (Kendall 1902). Norton reported that wading birds showed a marked increase for three decades after protection, which was followed by another decline for which he gave no explanation (Palmer 1949). During this period the only colonially nesting species were the great blue heron and black-crowned night heron.

Wading birds in general are probably more abundant in Maine today than in any previous period. Evidence for this is indirect, however, as no systematic inventories were conducted until the mid-1970s. Currently, all species of wading birds, except the black-crowned night heron, are increasing in Maine. The number of species breeding along coastal Maine is also increasing. The snowy egret first nested in Maine in the early 1960s. The glossy ibis, little blue heron, and Louisiana heron now breed in Maine south of region 1, and nonbreeding individuals of these species have been observed in all six regions of the characterization area.

Present Status of Wading Birds

Breeding birds. Of the six species of wading birds breeding in the characterization area, the great blue heron, black-crowned night heron, and snowy egret nest in single or mixed-species colonies, and the green heron and least and American bitterns nest solitarily.

There are 22 nesting colonies of wading birds in the characterization area, most of which (90%) are on islands. The location of each colony is plotted on atlas map 4. The great blue heron is the most abundant colonial nesting wading bird (table 14-15). Over 900 pairs nested in 19 different colonies during 1977 (Korschgen 1979; and Tyler 1977), which constituted the largest breeding population of any state north of New Jersey (Osborn and Custer 1978). Seventy-nine pairs of black-crowned night herons nested in four colonies along coastal Maine in 1977, and seven pairs of snowy egrets nested in two colonies. The snowy egret is at the northern limit of its breeding range in Maine. However, it is extending northward and can be expected to nest in other locations in the characterization area in the future. Three other species of colonial nesting wading birds, the little blue heron, Louisiana heron, and glossy ibis, are also extending their breeding ranges northward. These species currently nest along the Maine coast south of the characterization area.

Breeding populations of green herons, and least and American bitterns are more difficult to determine than those of colonial nesters and are currently unknown. The green heron is common around estuarine intertidal emergent wetlands, where it nests in trees. It also may be found in palustrine wetlands. The least and American bitterns nest on the ground in emergent vegetation such as cattails, bulrushes, and sedges. The American bittern is fairly common in palustrine habitats and, to a lesser extent, in estuarine intertidal emergent wetlands. The least bittern is known to nest at only two locations in Maine; a brackish marsh in Newcastle (region 2) and Bear Brook Pond in Acadia National Park (region 5).

Wading birds arrive on their nesting grounds in early to mid-April. Eggs are laid in late April and early May and hatch between late May and June. Young fledge from mid-July through early August. Most herons leave Maine in October and November to winter in southern States. A few (mostly great blue herons) attempt to overwinter.

Feeding Habits

Wading birds usually feed by 'standing and waiting' and 'walking or stalking.' Other methods include 'disturbing and chasing,' 'aerial feeding,' 'plunge/diving,' and 'swimming.' Most feed in the daytime but the black-crowned night heron feeds in the evening and at night (Kushlan 1976).

Wading birds may feed with others of their own or different species and sometimes with terns (Bertin 1977), pied-billed grebes (Mueller et al. 1972), mergansers (Emlin and Ambrose 1970), or shorebirds. In these associations different species may feed directly on the same prey or feed on prey disturbed by other waterbirds.

In Maine estuaries, wading birds feed mostly on killifish, minnows, eels, crustaceans, insects, and occasionally birds, small mammals, and plant material (tables 14-16 and 14-17) . In palustrine, riverine, and lacustrine habitats they feed on a variety of fish, frogs, tadpoles, small mammals, birds, crustaceans, and insects. On land they take a variety of amphibians, small mammals, and insects.

Table 14-15. Estimated Number of Pairs of Wading Birds (number of colonies in parenethèsis) Breeding in Each Region of the Characterization Area in 1977[a].

Species	Region						Total
	1	2	3	4	5	6	
Great blue heron	95 (2)	75 1	150 (1)	188 (7)	340 (4)	57 (3)	905 (19)
Black-crowned night heron	41 (2)		30 (1)	8 (1)			79 (4)
Snowy egret	6 (1)					1 (1)	7 (2)

[a]Tyler 1977; Korschgen 1979.

Table 14-16. Preferred Feeding Habitats of Wading Birds of Coastal Maine

Species	Intertidal mudflats	Marshes	Pools	Streams	Fields
Great blue heron	+	+	+	+	
Green heron	+	+	+	+	
Little blue heron	+	+	+	+	
Cattle egret		+			+
Great egret	+	+	+		
Snowy egret	+	+	+		
Louisiana heron	+	+	+		
Black-crowned night heron	+	+			
Yellow-crowned night heron	+	+			
Least bittern		+			
American bittern		+	+	+	
Glossy ibis	+	+	+		

Table 14-17. Preferred Food of Wading Birds of Coastal Maine

Species	Invertebrates	Fish	Reptiles and amphibians	Birds	Mammals
Great blue heron	+	+	+		+
Green heron	+	+			
Little blue heron	+	+			
Cattle egret	+				
Great egret	+	+	+		+
Snowy egret	+	+	+		
Louisiana heron	+	+	+		
Black-crowned night heron	+	+	+	+	+
Yellow-crowned night heron	+	+			
Least bittern	+	+	+		
American bittern	+	+	+		
Glossy ibis	+	+	+		

HUMAN IMPACTS ON WATERBIRDS

Since the late 1800s many human activities have had both positive and negative effects on waterbird populations. Disturbance during the breeding season, loss of valuable feeding and nesting habitat, and environmental contamination by oil, heavy metals, and organochlorine compounds are currently the major threat to waterbirds in Maine. Some of the positive effects of people in coastal Maine include the protection of waterbirds by law, the preservation of certain key waterbird colonies, and the inadvertent creation of upland feeding areas for shorebirds partial to cleared land.

This section will discuss how habitat loss, environmental contamination, and disturbances by people affect waterbirds.

Habitat Loss

Excessive loss of important breeding, feeding, and nesting habitat is detrimental to most waterbirds. Losses include the complete elimination of a specific habitat such as the filling of a wetland or construction on most small islands. Sheep grazing or timber harvesting on bird islands may seriously reduce nesting cover. Terns, laughing gulls, and Leach's storm petrels have been affected the most by these activities (Drury 1973) .

Tidal Power

Tidal power, which is yet to be developed in Maine, is given special consideration here because the feasibility of developing several large scale tidal power projects has been under investigation (Cobscook Bay in region 6 and Taunton Bay in region 5).

Impoundments created by tidal barrages are likely to adversely affect birds that feed on intertidal mudflats and in the vicinity of deepwater tidal rips. The degree to which an estuary or the adjacent marine deepwater ecosystems will be affected depends on characteristics of the estuary and the type of generation facility used (e.g., turbine type, one or two pool impoundments, and position of the sluice). Several generalizations based on existing and planned tidal obstructions may be made.

The area of intertidal mudflats that is presently exposed is likely to be reduced because tidal amplitude is reduced (especially along the lower tide range), water is temporarily impounded and will cover mudflats (feeding areas will be available for shorter periods of time), and water may be inadvertently obstructed by the barrage (i.e., the area below lower turbine level) or deliberately retained for peak power generation beyond the normal period of low tide.

Increased sedimentation behind the impoundment may alter the species composition and abundance of mudflat invertebrates (Yeo 1978; Risk et al. 1977). Such changes occurred in a barrage-like impoundment in the northern Bay of Fundy (Yeo 1978). Lower densities and biomass of important shorebird foods, such as the small amphipod *Corophium volutator*, were found in the substrates behind the obstruction. Lower shorebird numbers also have been reported in that area (personal communicatione from S. Boates, Acadia University, Wolfville, Nova Scotia, Canada; June, 1979). Species most likely to be adversely affected by loss of habitat and changes in food availability due to tidal barrages include shorebirds (particularly semipalmated sandpipers, semipalmated plovers, and black-bellied plovers), Bonaparte's gulls, herring and black-backed gulls, and great blue herons. Altered tidal flow and regimes that cause changes in such factors as salinity, turbidity, temperature, and nutrient content interact to affect invertebrate communities. This, in turn, affects their avian predators.

Species feeding in or among tidal rips, tidal convergences, and tidally-related upwellings might be adversely affected if these oceanographic features are altered. One of the largest inshore tidal rips and upwelling areas in the eastern U.S. occurs in waters off Eastport, Maine (region 6). Tides ebbing from Cobscook Bay converge with waters draining Passamaquoddy Bay to form rips and convergence lines. High tidal ranges and local bottom topography contribute to the dynamics of this system. This area is a major feeding area for northern phalaropes, Bonaparte's gulls, herring and black-backed gulls (10,000 to 50,000), kittiwakes, and dovekies. Altering the timing of water draining either bay may affect the position, extent, and duration of the tidal rips, which may sharply reduce the abundance of food on which these birds feed.

Tidal amplitude outside the enclosed area also is likely to increase, which may affect the amount and quality of intertidal feeding areas. Estuarine emergent wetlands (salt marshes) are likely to be adversely affected by altered tidal amplitude, but intertidal mud flats might increase offsetting losses inside the barrage.

Environmental Contamination

Several types of environmental pollutants may adversely affect survival and reproduction of waterbirds. These include oil, pesticides and other toxic chemicals, heavy metals, and industrial and domestic wastes. Several excellent reviews of the effects of environmental contamination on waterbirds (including waterfowl) have been published in technical journals. Much of this section was summarized from the review papers of Ohlendorf and coworkers (1978a), Howe and coworkers (1978), Farrington (1977), Lincer (1977), and Albers (1977 and 1978).

Oil. Contamination of marine and estuarine systems by oil poses a serious threat to waterbirds along the Maine coast. Oil enters coastal waters by spillage during transfer operations, discharges from refineries, regular discharges from inhabited areas (street runoff, sewage discharge, and boating), and by catastrophic spills. The extent of oil contamination in Maine is discussed in chapter 3, "Human Impacts on the Ecosystem." Casco Bay (region 1) and Penobscot Bay (region 4) have the largest numbers of oil spills in Maine.

The most serious effect of oil spills on waterbirds is feather oiling. Oil disrupts the structure of feathers, destroying their insulating properties and buoyancy. Moderately or heavily oiled birds drown or die of exposure. The latter is potentially serious in the cold waters along the Maine coast.

A number of oil or petroleum products are toxic to birds. Birds ingest oil while preening oil-coated feathers, drinking, or eating oil-covered food, and may die or suffer physiological or behavioral changes, including reproductive failure (Crocker et al. 1974 and 1975; Grau et al. 1977; Miller et al. 1977; Szaro et al. 1978a; and Wooton et al. 1979). Birds may also ingest petroleum products contained in tissues of fish or marine invertebrates.

Nesting birds can transfer oil from their feathers or feet to eggs while incubating. Small amounts of oil (equal to a few drops) can kill embryos inside the eggs (Albers 1977; Szaro and Albers 1977; Albers and Szaro 1978; Szaro et al. 1978b; and others). Bird embroys are most sensitive during the first 10 days of incubation.

Oil spills also damage marine and intertidal environments where waterbirds feed, nest, and roost. Birds often abandon areas after an oil spill because habitat quality is poor and prey populations are reduced (Buck and Harrison 1967; Abraham 1975; and Hope Jones et al. 1978). Recovery can take as long as 10 years.

Among the waterbird groups, seabirds are probably most vulnerable to oil spills because they have a greater chance of coming in contact with oil. Seabirds that spend most of the time on the water, such as eiders, cormorants, alcids, loons, and grebes, are more susceptible to feather-oiling than species that feed on the wing (such as petrels, terns, and, to a lesser extent, gulls). All species of seabirds that breed along the coast of Maine could suffer reduced reproductive success from egg-oiling if a spill occurred during the nesting season (April to June).

Shorebirds would be most vulnerable to spills during migration, particularly if spills occurred or washed ashore at night when large numbers of birds are concentrated on roosts near the waters edge. Wading birds are less susceptible to feather oiling than other waterbirds because they have long legs and their feathers do not always come in contact with the water, but oil could be transferred from their feet to eggs.

Toxic chemicals. The most important toxic chemicals in marine and estuarine systems are the chlorinated hydrocarbons, DDT and its metabolites DDD and DDE, and polychlorinated biphenyls (PCBs). Use of DDT has been banned in the U.S., so little or no DDT, DDD, or DDE currently enter Maine waters. Migratory birds may be exposed to these chemicals in wintering areas outside the U.S. PCBs are used primarily for industrial products, such as heat exchangers and condensors (Ohlendorf et al. 1978a). Large quantities of PCBs enter the marine system primarily in industrial waste, sewage sludge, and when plastics are burned and transported in the atmosphere. These chemicals occur in concentrations around industralized areas (Howe et al. 1978).

Chlorinated hydrocarbons are chemically stable, relatively insoluble in water, and may remain in the ecosystem for long periods of time. They can accumulate in the fat of organisms and concentrations can magnify as they pass from prey to predator along the food chain. Very little is lost by way of excretion. Concentrations are highest in species of birds such as eagles, ospreys, herons, and terns, that feed on fish. For this reason fish-eating species make good indicators of the abundance of hydrocarbons.

Chlorinated hydrocarbons may affect birds directly by killing them or by interfering with their reproductive processes (i.e., eggshell thickness) and indirectly by killing their food supply. Direct mortality may occur when birds are under unusual physiological stress and fats are being mobilized (Ohlendorf et al. 1978b). Stress occurs during migration, periods of food shortage (especially in winter when intertidal flats are ice-covered), during reproduction, disease or injury, and after exposure to oil or other environmental hazards. Female eiders may be particularly vulnerable because they do not feed during incubation. Dead eiders with high concentrations of DDT were found on nests in the Netherlands (Howe et al. 1978). Females of most species may be vulnerable during the egg-laying period because fat reserves are used for egg synthesis.

Heavy metals. Heavy metals in the environment, particularly mercury and lead, have caused biologists to be concerned about effects on birds. Mercury enters the environment through a variety of sources, including fungicides, germicides, industrial uses, heating or burning of fuels and ores, and from oil discharges from ships and refining industries (Merlini 1971; and Howe et al. 1978). The most toxic form is methyl mercury (Westoo 1967; and Fimreite 1974). Mercury may accumulate in birds as it passes through the food web. In Maine it is found in eels, mergansers, and eagles (see chapter 15, "Waterfowl"). It probably occurs in other waterbirds that feed extensively on eels, or those (such as herons) that feed on the same prey as eels.

Lead enters the environment mostly from industrial, automotive, and municipal sources and from lead shot (Howe et al. 1978). Waterfowl mortality from lead poisoning may reach between 1.5 and 2 million birds each year in the United States (Banks 1979). Lead is not known to accumulate in food chains. Eagles may injest lead shot from the flesh of their prey, usually ducks.

Plastic and other artifacts. Small particulate pollution composed mostly of plastic beads and irregular shaped particulates up to 0.2 inches (0.5 cm) in diameter is commonly found in plankton samples and is found in the stomachs of birds and fish that feed on plankton (e.g., plastic has been found in Leach's storm petrels in New Brunswick) and birds that feed on plankton-feeding fish. The effects on birds are relatively unknown but intestinal blockage may be one possible consequence (Ohlendorf et al. 1978a). Small rubber thread cuttings are often ingested by common puffins who mistake them for fish (Ohlendorf et al. 1978a). These may accumulate into entangled balls of rubber in the gizzard.

Larger waste materials are problems along beaches where birds may become entangled in kite strings, fishing lines, plastic containers, and "six-pack" containers. The wrack line is often the source of many potential hazards. Birds foraging in dumps may also encounter these hazards. In one common tern colony in New York 14 young and 7 adults were found trapped by kite strings (Howe et al. 1978). The magnitude of these problems in Maine has not been investigated but several instances of entangled birds have been observed.

Other Disturbance

Disturbance by people has the greatest adverse impact on a nesting colony. Picnicking, bird watching, nature tours, and other activities disturb nesting waterbirds. Deliberate vandalism, of course, has the most injurious effect of all. Eggs and young are vulnerable to predation (Drury 1973; Hunt 1972; Nisbet 1973; Mendall 1976; and Robert and Ralph 1975), chilling and overheating, and the young may starve if the adults are kept from feeding them. The presence of sheep, pets, and pests associated with human habitation results in disturbance to, and even destruction of, colonies. Cats and dogs have had particularly harmful effects on several former storm-petrel colonies (Gross 1935). Least terns, common loons, and piping plovers are especially vulnerable because they nest on the mainland, where human disturbance is greater. Nesting success of least terns is lower on Popham Beach than on nearby Sprague River Beach, perhaps because the former is much used while the latter is less so, being privately owned. Breeding success of common loons is low in southwestern Maine compared to other parts of the State, primarily because of unnatural fluctuations in water levels, harrassment by motor boats, numerous shoreline cottages and predation by raccoons attracted by cottages and camps.

Birds are more sensitive to disturbance by people early in the nesting cycle (prelaying and laying stages) and will abandon their nests more readily then than after the young have hatched. However, many species can renest if nests are lost or abandoned early, whereas renesting is seldom attempted if young are lost.

MANAGEMENT

The U.S. Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildlife are jointly responsible for managing waterbirds along the Maine coast. This primarily involves protection. Problems concerning management should be directed to those agencies.

The continued existence of healthy populations of waterbirds along the Maine coast depends on maintaining adequate amounts of breeding, feeding, and roosting habitats. Development of shorelines and coastal islands, or high levels of human activity could cause birds to abandon important habitats. Owners of these areas, or those who control access, developers, planners, and the general public, need to be made aware of the necessity of protecting nesting, feeding, and roosting habitats.

RESEARCH NEEDS

More information is available on waterbirds than on most other groups of vertebrates found along the Maine coast. Nonetheless, there are areas in which further information is needed.

Basic inventories of nonbreeding, migrating, and wintering seabirds, migrating and wintering shorebirds, and nonbreeding wading birds need to be made on a regional basis to determine the abundance of various groups throughout the coastal zone and the periods during which they are present. The locations and seasonal uses of various types of habitats, such as feeding and roosting habitats for shorebirds, tidal upwellings, mudflats, brood-rearing areas for terns, and post-breeding molting areas for eiders, need to be documented.

Breeding populations of solitary nesting waterbirds, such as spotted sandpipers, common loons, and American bitterns, need to be assessed in coastal Maine, and breeding colonies of colonial nesting species need to be monitored.

The effects of human visitation, pets, livestock grazing, buildings, and other human activities on breeding seabirds need to be determined, and the extent to which these activities affect current colonies needs to be assessed.

The influence of human disturbance (dogs, bird watchers, boats, and clam-diggers) on concentrations of feeding and roosting shorebirds, and the degree of the problem along the coast of Maine needs to be determined. If human disturbance is found to be adversely affecting waterbirds, methods need to be devised to mitigate or eliminate these disturbances.

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Chapter 15
Waterfowl

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The waterfowl of coastal Maine (ducks, geese, and swans of the family Anatidae) are a higly visible and valuable natural resource. Because most waterfowl are migratory, they are managed by regulatory controls and habitat protection or improvement by Federal and State agencies and by international agreement.

Waterfowl inhabit a wide range of aquatic habitats and some terrestrial habitats, consequently their seasonal distribution and daily movements in coastal Maine are controlled largely by the abundance and diversity of available habitat, and by habitat change and alterations. The general abundance of most species of waterfowl of coastal Maine are largely determined by conditions that prevail in their breeding and wintering grounds outside of Maine. The diversity of the waterfowl habitat of coastal Maine (feeding, breeding, nesting, and wintering grounds in freshwater, estuarine, and marine habitats) is demonstrated by the diversity of waterfowl found there.

This chapter attempts to identify major waterfowl resources and their seasonal distribution and abundance along the coast of Maine, their interactions among ecosystem components, and their response to human-induced factors and management.

The common and scientific names (American Ornithologists' Union 1957, 1973a, 1973b, and 1976) and the relative abundance of the waterfowl species among resident, breeding, wintering, and migratory populations of coastal Maine, based on most recent estimates, are given in tables 15-1 to 15-4. Of the 140 species of waterfowl now recognized in the world, about 45 breed in North America (Johnsgard 1975). Thirty-six of the North American species breed in, migrate through, or winter in coastal Maine in sufficient numbers to be considered in this report. One of these, the eider duck, is also discussed in chapter 14, "Waterbirds", because of its breeding distribution.

Table 15-1. Resident Waterfowl Species in the Characterization Area

Common name	Scientific name[a]	Relative abundance[b]		
		Breeding	Migration	Wintering
Black duck	*Anas rubripes* (Brewster)	Abundant	Abundant	Abundant
Mallard	*Anas p. platyrhynchos* (Linnaeus)	Rare	Common	Common
Common goldeneye	*Bucephala clangula* (Linnaeus)	Rare	Abundant	Abundant
American eider	*Somateria mollissima dresseri* (Sharpe)	Abundant	Abundant	Abundant
Hooded merganser	*Lophodytes cucullatus* (Linnaeus)	Common	Common	Rare
American merganser	*Mergus merganser* (Linnaeus)	Common	Common	Common
Canada goose	*Branta c. canadensis* (Linnaeus)	Rare	Abundant	Common

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).
[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

Table 15-2. Breeding Waterfowl Species in the Characterization Area

Common name	Scientific name[a]	Breeding abundance[b]	
		Breeding	Migration
Wood duck	*Aix sponsa* (Linnaeus)	Common	Common
Ring-necked duck	*Aythya collaris* (Donovan)	Common	Common
Blue-winged teal	*Anas discors* (Linnaeus)	Common	Common
American green-winged teal	*Anas crecca carolinensis* (Gmelin)	Common	Common

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).
[b]Abundant = seen regularly in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

Table 15-3. Wintering Waterfowl Species in the Characterization Area

Common name	Scientific name[a]	Relative abundance[b]	
		Migration	Winter
Greater scaup	_Aythya marila_ (Linnaeus)	Common[c]	Common[c]
Bufflehead	_Bucephala albeola_ (Linnaeus)	Abundant	Abundant
Old squaw	_Clangula hyemalis_ (Linnaeus)	Abundant	Abundant
Harlequin	_Histrionicus histrionicus_ (Linnaeus)	Rare	Rare
King eider	_Somateria spectabilis_ (Linnaeus)	Rare	Rare
White-winged scoter	_Melanitta deglandi_ (Bonaparte)	Abundant	Abundant
Surf scoter	_Melanitta perspecillata_ (Linnaeus)	Common	Common
Black scoter	_Melanitta nigra_ (Linnaeus)	Common	Common
Red-breasted merganser	_Mergus serrator_ (Linnaeus)	Abundant	Abundant
Barrow's goldeneye	_Bucephala islandica_ (Gmelin)	Rare	Rare

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).
[b]Abundant = regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).
[c]Usually occur in flocks exceeding 100 but rather erratic and limited distribution.

Table 15-4. Migrant Waterfowl Species in the Characterization Area

Common name	Scientific name[a]	Relative abundance[b] Migration
Whistling swan	*Olor columbianus* (Ord)	Rare
Brant	*Branta bernicla brota* (Muller)	Common (spring)
White-fronted goose	*Anser albifrons* (Scopoli)	Rare
Lesser snow (blue) goose	*Chen c. caerulescens* (Pallas)	Rare
Greater snow goose	*Chen caerulescens atlanticus* (Kennard)	Abundant
Gadwall	*Anas strepera* (Linnaeus)	Rare
Pintail	*Anas acuta* (Linnaeus)	Common
European wigeon	*Anas penelope* (Linnaeus)	Rare
American wigeon	*Anas americana* (Gmelin)	Common
Northern shoveller	*Anas clypeata* (Linnaeus)	Rare
Redhead	*Aythya americana* (Eyton)	Rare
Canvasback	*Aythya valisneria* (Wilson)	Rare (spring)
Lesser scaup	*Aythya affinis* (Eython)	Common

[a]According to A.O.U. (1957, 1973a, 1973b, 1976).
[b]Abundant = seen regularly and in numbers (100's); common = seen regularly but not in numbers (10's); rare = seen irregularly in small numbers (less than 10).

(Continued)

Table 15-4. (Concluded)

Common name	Scientific name[a]	Relative abundance[b] Migration
Ruddy duck	*Oxyura jamaicensis* (Gmelin)	Common
Fulvous whistling duck	*Dendroeygna bicolor* (Vieillot)	Rare

Waterfowl in Maine annually support about 140,000 person-days of hunting and a kill of 100,000 retrieved birds. The hunting pressure and kill for coastal Maine, which is about two-thirds of the state total, has generated an important recreational and hunting industry for a number of coastal communities, and emphasizes coastal habitats and estuarine systems as critical waterfowl habitat.

Although waterfowl are a widely recognized resource, needs for their protection and management sometimes are controversial. For example, the eider duck feeds heavily on cultured mussels, which has raised an unresolved conflict of interest. The magnitude of human destruction of the natural habitat of waterfowl in some areas of the coast of Maine is disturbing. Oil spills, toxic wastes (e.g., pesticides and heavy metals), and increased recreational boating are examples of environmental problems. Waterfowl are an intergral component of coastal Maine and coastal zone planning and management.

Much of the data for this chapter were drawn from the Maine Department of Inland Fisheries and Wildlife (MDIFW) division files at the Orono Research Section. Waterfowl often are associated with seabirds (e.g., gulls, terns, and cormorants), shorebirds (e.g., phalaropes, plover, and yellowlegs), and raptors (e.g., eagles and hawks), and the interactions of some of these groups are described in chapter 14, "Waterbirds", and chapter 16, "Terrestrial Birds."

Because much of the literature on the waterfowl of Maine has been prepared for counties and research units, or for the state as a whole, it is sometimes difficult to identify the data with particular regions of the characterization study area, but its general application to coastal Maine is reasonably clear.

Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

WATERFOWL GROUPS

To better understand waterfowl populations and their interactions with ecosystem components, waterfowl populations or species may first be identified as "groups" based on migratory habits or residential status. Using these criteria, waterfowl are grouped as resident, breeding, wintering, and migrant species (Palmer 1949; and Spencer 1975). These groups, as used in this chapter, are overly simplified because some or all species or populations are migratory at one time or another.

A brief description of the groups are as follows:

1. Resident species. Those present throughout the year (table 15-1).

2. Breeding species. Those that breed in Maine but usually winter elsewhere (table 15-2).

3. Wintering species. Overwintering migrants (table 15-3).

4. Migrants. Those species that are usually present only during spring and fall migration (table 15-4).

More detailed descriptions of these groups (based upon Palmer 1949; Spencer 1975; and unpublished data of Maine Department of Inland Fisheries and Wildlife) are given below.

Resident Waterfowl

Although the term resident, as defined here, is useful, it should not be interpreted literally to mean the same individuals of a species remain in Maine throughout the year. For example, black ducks and goldeneyes that breed in Maine may winter elsewhere, and most black ducks and goldeneyes that winter on the Maine coast may breed elsewhere. Only a few waterfowl are permanent breeding residents. Black ducks probably come the closest; some breed in inland waters but winter along the coast.

Among the resident species listed in table 15-1, the black duck is by far the most important because it is highly sought as a game bird, rates high as a table bird, and comprises over 30% of the annual statewide waterfowl kill. A ground nester, the black duck is abundant throughout the year in coastal Maine and comprises at least 35% of the breeding population. From 10,000 to 30,000 black ducks winter on the Maine coast.

The mallard has always been present in Maine but in small numbers. Mixed pairs of male mallards and female black ducks commonly occur. The mallard is as popular and widely sought as the black duck, but the mallard comprises less than 5% of the annual hunting kill. In winter most mallards are scattered among the black duck flocks, some of which are domestic mallards turned wild.

The goldeneye, an inland breeder, is the only resident diving duck in Maine. It breeds mostly in northeast Maine but is thought to also breed occasionally in eastern and central Maine. Banding data indicate very few goldeneyes reared in Maine are brought down by hunters, or winter in Maine. The origin of migrating or wintering goldeneyes is not known. This duck contributes only about 3% of the annual hunter's kill. The goldeneye, and the smaller bufflehead, comprise much of the coastal duck hunting when black ducks are scarce.

The hooded and American mergansers appear to qualify as residents. The hooded merganser breeds throughout the state. The American merganser, much less abundant than the hooded merganser, also thrives throughout the state but tends to avoid the more southerly coastal areas. Although the mergansers are not usually considered a desirable table bird because of their fish eating habits, they comprise about 2% of the annual hunting take. From 2000 to 3000 mergansers winter along the coast.

The American merganser breeds in small numbers along the coast. Among the ducks, the size and survival of the broods of individual mergansers are unusually high. Factors limiting their general abundance in coastal Maine are not known. In winter this duck is common offshore, usually near islands or in tidal estuaries. Pilot studies suggest this species may serve as an indicator of biocides and heavy metals in coastal waters (personal communication from R. B. Owen, Jr., School of Forest Resources, University of Maine, Orono, ME.; February, 1979).

The American eider is Maine's only resident sea duck (ducks that usually inhabit nearshore coastal waters). It is abundant as a breeder from Machias Bay southwesterly to Cape Elizabeth (see atlas map 4). It winters in abundance from Narraguagus Bay, Washington County, to Cape Neddick, York County. Although eiders also are abundant in the winter off Cape Cod, Massachusetts, few have been observed in southern Maine. Small numbers are observed in Machias Bay but none in Cobscook Bay.

The Canada goose has been a resident of Maine primarily because of propagation and release programs at the FWS Moosehorn National Wildlife Refuge, and a transplant program by MDIFW. At least 40 broods comprised of 170 goslings were hatched in Maine in 1977 (Spencer and Corr 1977). A few of these birds were planted in the characterization area. Most of the Canada geese apparently remain in Maine during the year.

Breeding Species

The wood duck is by far the most abundant and universally distributed breeding duck in Maine, but few inhabit the estuarine or coastal waters (table 15-2). They are most abundant as breeders in the central and southwest regions (regions 1, 2, and 3) and less numerous in the northeast (regions 4, 5, and 6). This species heavily utilizes managed beaver impoundment areas and well conceived and managed nest box programs. The wood duck is the most numerous of the three cavity-nesting waterfowl (the others are the goldeneye and hooded merganser). It is one of the most beautiful of waterfowl, a dabbling species (feeds on or near the bottom by tipping), and a highly desirable game and table bird. Although it is an early fall migrant (it is implied in this chapter that fall migrants may fly south as early as July), and near the northern limits of its range, the statewide hunting kill in 1976 was 10,000 ducks (only black duck and green-winged teal exceeded that number). In early fall, during migration, wood ducks tend to congregate along the coast where most of the wood ducks are taken by hunters. Hunting mortality would be higher if the wood ducks did not migrate south so early in the hunting season.

The blue-winged and green-winged teal make up a small but regular component of the waterfowl breeding population of coastal Maine. The blue-winged teal is a predominantly freshwater bird that prefers shallow, grass/sedge, emergent, palustrine wetland as breeding habitat. It is a very early fall migrant and is abundant in the coastal areas only in late August and early September. Due to their early migration, they are not a reliable part of the hunter's harvest. For example, the annual estimated Statewide blue-winged teal killed from 1975 to 1977 was 2483, 2814, and 663 respectively.

The green-winged teal, as a breeder, is less numerous than the blue-wing in coastal Maine. The green-winged teal prefers smaller palustrine wetlands for breeding purposes and is often found in the shrub/scrub class of palustrine habitat. Apparently the migrant contingent of the species is fairly abundant in coastal waters from late August until mid-November. Although they seem to prefer inland freshwater habitats, they occasionally inhabit estuarine areas. The green-winged teal traditionally is the second most important duck for hunting in Maine. Although it probably is the smallest of game ducks, it is highly sought in Maine and is an excellent table bird. Hunters killed 8000 to 12,000 green-winged teal annually from 1975 to 1977, contributing 11% to 14% of the state total.

The ring-necked duck, a diving species, breeds throughout coastal Maine, but prefers the deeper palustrine and riverine marshes. Most local birds migrate south in September and all are usually gone by the end of November. This species, rarely observed on saltwater in Maine, makes up from 1% to 4% of the hunter's bag. Region 6 supports the major coastal breeding population.

Wintering Species

Among the wintering species, only the bufflehead, old squaw, and white-winged scoter are widely distributed and relatively abundant in the coastal area. Although greater scaup occur mostly in flocks of over 100 birds, they are traditionally observed in only a few specific areas, which may reflect rather specific habitat requirements in the winter.

Although not classified as wintering species, as given in table 15-3, large numbers of other species winter in the estuaries and bays of the Maine coast. Major overwintering birds, in order of abundance from 1975 to 1977, are eiders and black ducks, which make up the majority, goldeneyes, scaups, and buffleheads.

Migrants

Among the migrant species of coastal Maine, brant, greater snow geese, and lesser scaup are observed regularly in flocks up to several hundred but generally only in specific areas at specific times (table 15-4). Pintails, and other migrant waterfowl not mentioned above, occur incidentally as singles or small flocks (<10) in estuaries and coastal waters.

WATERFOWL ASSESSMENT

The problems associated with monitoring and managing waterfowl populations were reviewed by the U.S. Fish and Wildlife Service in a recent environmental impact statement (U.S. Fish and Wildlife Service 1975), part of which says:

> "The situation with migratory birds is similar to that for most other wild animal populations in which the condition of the resource is monitored by a variety of techniques that yield information used in evaluating the status of each population. ...Habitat surveys, indices of population size, band recovery rates, production estimates, survival estimates, and harvest information are used to evaluate population status."

All of the above methods have been used to some extent by the Maine Department of Inland Fisheries and Wildlife (MDIFW) to assess Maine waterfowl populations. Since the early 1970s, as a result of comprehensive waterfowl planning by FWS, most surveys and investigation data have been recorded and analyzed on a "wildlife management unit" basis. These units are shown in figure 15-1 for comparison with the regional boundaries of the characterization area. Figure 15-2 gives a simlar comparison of the characterization area with winter waterfowl inventory units established by the MDIFW in 1952. Figure 15-3 shows how the coastal county boundaries are positioned in relation to the characterization area. Selected data from MDIFW investigations are summarized and discussed below.

Figure 15-1. The wildlife management units (large numbers, dashed lines) and the characterization region (small numbers, light lines) in Maine (Maine Department of Inland Fisheries and Wildlife).

Figure 15-2. Maine Department of Inland Fisheries and Wildlife winter waterfowl inventory units (large numbers, dotted lines) and characterization regions (small numbers, light lines) in Maine (Maine Department of Inland Fisheries and Wildlife).

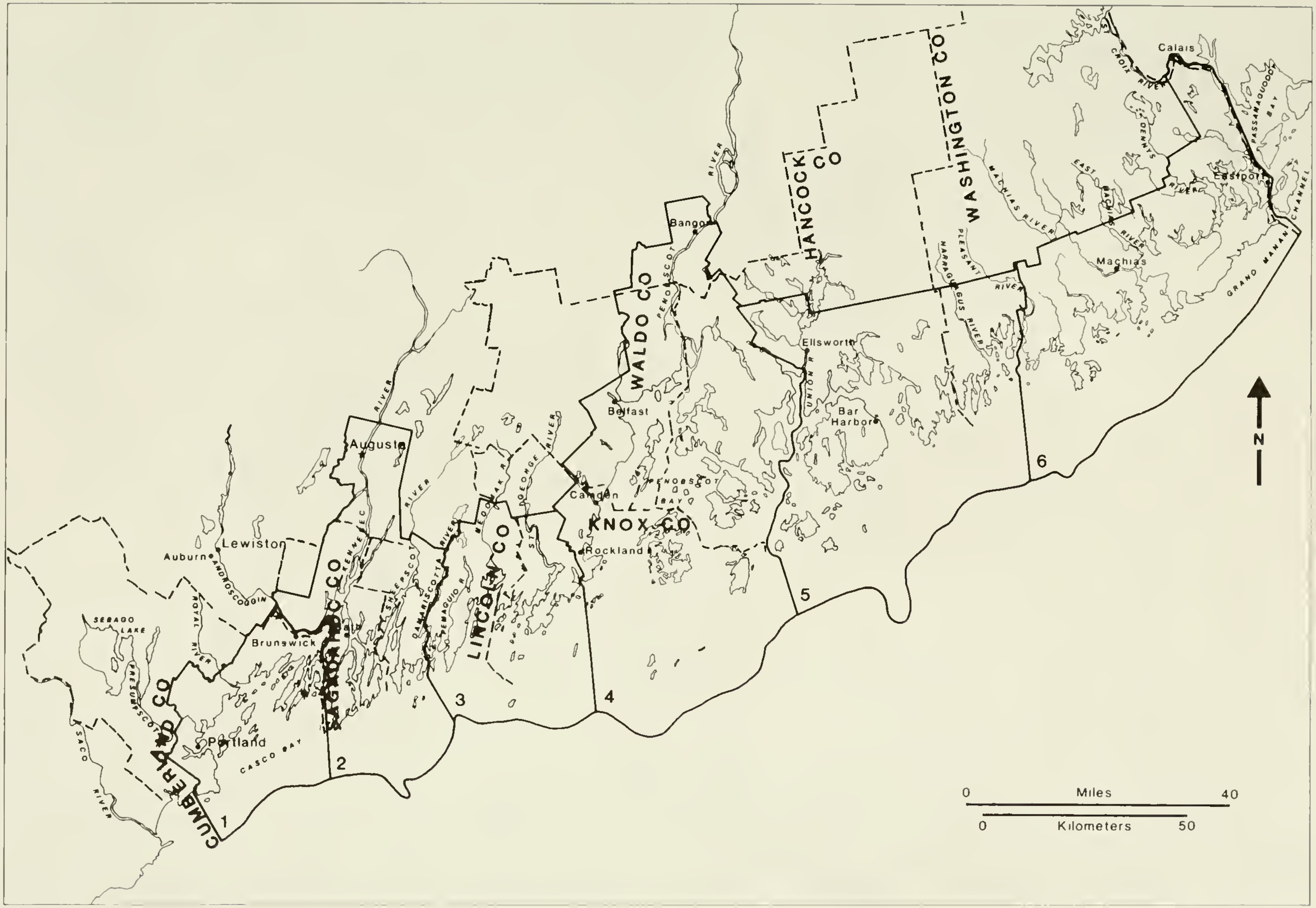

Figure 15-3. Boundries of coastal counties and characterization regions (Maine Department of Inland Fisheries and Wildlife).

The winter inventory is an aerial survey conducted annually by much the same personnel over the same area during the first two weeks in January. It provides the only direct visual estimates of Maine's waterfowl populations. Waterfowl counts are made at elevations between 100 and 300 feet. The entire shoreline, including islands and ledges, are surveyed in each wildlife management unit. A number of factors may influence the accuracy of the counts.

Light and tide conditions vary constantly during the course of the survey, and several species form into common flocks. Color patterns and flight characteristics of goldeneyes, bufflehead, and mergansers are most easily differentiated. Other common waterfowl of Maine are readily identifiable because they occur in small flocks, usually less than 100. In Chesapeake Bay and Bear River marshes, flocks number in the tens of thousands, whereas in Maine, flocks rarely reach 500 individuals, and most are much smaller. Because of probable error and limitations just described, statistical appraisal is not applicable. The annual wintering population estimates for major species from 1952 to 1979 are shown in table 15-5. The annual population estimates of 8 species of wintering waterfowl are given for each waterfowl inventory unit (figures 15-4 to 15-11).

Among the species in the winter inventory, the black duck is perhaps the easiest to identify, consequently, winter estimates of its abundance are likely to be most accurate. The increase in black duck counts Statewide from 1960 to 1975, and the sharp decline in Casco Bay, Muscongus Bay, and Penobscot Bay units since 1975 are unexplainable. The winter population estimates for most duck species were much higher in 1975 than in 1979 (table 15-5). It is not known whether the wintering population changes reflected by the data were caused by weather or other factors in the wintering grounds, or by habitat alteration or breeding failures in other areas of its overall range.

Breeding Populations

The status of waterfowl breeding populations in coastal Maine and the wildlife management units is best assessed by using the results of a recent compilation of 21 years of production data (MDIFW). The numbers of broods of each species were counted periodically and listed by wetland type or by wildlife management unit. The data in tables 15-6 to 15-8 are used in this analysis. The species composition of breeding waterfowl populations in the coastal wildlife management units in 1956 to 1965 and 1966 to 1976, and the State as a whole, are given in table 15-6. Breeding ducks were largely black ducks, wood ducks, ring-necked ducks, and goldeneyes. The data also show a sizeable reduction in the percentage of black ducks and wood ducks from 1956 to 1965 and 1966 to 1976, and an increase in ring-necked and goldeneye ducks. Although changes were shown for other waterfowl, the numbers were too small for analysis.

The duck brood estimates (eider excluded) for the waterfowl of Maine are based on the average number of duck broods per acre for seven inland wetland types from 1956 to 1965 and from 1966 to 1976 (table 15-7). These estimates probably are conservative because there are no data from several tidal wetland types which are known to produce young, and because the estimates are based on actual counts (many could have been missed).

Table 15-5. Estimated Numbers of Major Waterfowl Species in the Waterfowl Inventory Units of Coastal Maine in the Winters from 1975 to 1979.

Inventory units[a]	Year	Black duck	Mallard	Golden-eye	Buffle-head	Scaup	Scoters	Eiders	Old squaw	Merganser	Unident. ducks	Geese	Total
1	1975	10,913	200	4727	1862	1360	589	18,987	839	1164	1332	101	42,004
	1976	3282	34	2928	573	265	186	7815	239	3111	1043	141	19,617
	1977	2279	27	2080	896	325	67	12,772	236	1687	586	90	21,045
	1978	4319	39	2409	1055	255	395	12,846	569	2365	648	180	25,080
	1979	2435	8	862	782	60	35	11,841	51	1931	494	155	18,654
2	1975	1946	12	995	1713	100	0	5373	185	105	613	5	11,047
	1976	592	0	749	752	175	29	3561	435	17	210	10	6530
	1977	53	0	776	580	0	7	5297	655	5	247	0	7630
	1978	288	0	1144	673	10	23	3233	235	153	372	230	6361
	1979	209	1	339	401	0	0	7498	168	19	320	30	8985
3	1975	4097	11	2856	244	326	582	533	63	688	280	59	9719
	1976	1528	0	868	413	330	545	602	97	13	671	0	5067
	1977	1023	2	1345	417	128	443	966	100	177	143	50	4794
	1978	1266	4	796	86	340	378	643	59	239	314	60	4185
	1979	912	0	551	507	0	135	460	92	46	130	70	2903
4	1975	4277	22	1020	470	2527	1991	3305	141	59	1229	163	15,204
	1976	2249	2	1311	569	6070	805	4214	259	27	520	163	16,189
	1977	2084	0	1546	415	3855	2621	3387	246	112	678	353	15,297
	1978	2212	3	1155	381	2295	1282	2331	340	280	220	85	10,584
	1979	2028	0	797	244	2150	247	3332	113	65	102	200	9278
5	1975	4701	58	1039	313	0	2	5627	422	77	51	0	12,290
	1976	4875	8	110	162	25	115	2784	22	1	125	0	8227
	1977	1921	0	1013	1167	200	111	5859	348	20	336	0	10,975
	1978	4359	14	892	373	0	142	2713	169	26	81	0	8769
	1979	2690	27	1598	373	0	225	4016	216	74	192	0	9411

[a] 1=Casco Bay; 2=Muscongus Bay; 3=Penobscot Bay; 4=Frenchman's Bay; 5=Narraguagus Bay; 6=Machias Bay; 7=Cohscook Bay; 8=Kittery.

(Continued)

Table 15-5. (Concluded)

Inventory units	Year	Black duck	Mallard	Golden-eye	Buffle-head	Scaup	Scoters	Elders	Old squaw	Merganser	Unident. ducks	Geese	Total
6	1975	1680	7	610	73	0	5	38	157	66	13	0	2649
	1976	1616	6	39	247	0	133	0	9	0	27	0	2077
	1977	760	0	135	255	0	0	50	156	2	246	0	1604
	1978	1531	10	292	274	0	4	16	6	32	84	0	2249
7	1975	1708	9	522	37	0	438	0	77	128	501	0	3420
	1976	2562	13	186	244	0	99	0	5	21	118	20	3248
	1977	917	3	515	458	0	2	0	135	23	162	20	2235
	1978	1928	3	721	299	45	2	0	32	29	255	35	3349
	1979	2348	4	567	90	0	83	0	5	0	38	65	3200
8	1975	1448	32	756	465	0	225	5061	280	17	135	575	8994
	1976	700	1	290	22	0	115	901	104	4	223	333	2693
	1977	1564	0	421	117	0	503	1776	436	6	274	163	5260
	1978	1631	10	368	73	0	90	1359	105	41	192	287	4156
	1979	1089	20	74	90	0	50	3714	157	1	82	190	5467
Total	1975	30,770	351	12,525	5157	4313	3832	38,854	2164	2304	4154	903	105,327
	1976	17,404	64	6481	2982	6865	2027	19,877	1170	3194	2937	647	63,648
	1977	10,601	32	7831	4305	4508	3754	30,107	2322	2032	2672	676	68,840
	1978	17,534	83	7777	3214	2945	2316	23,141	1515	3165	2166	877	64,733
	1979	13,283	60	5058	2586	2210	775	30,915	975	2141	1397	710	60,110

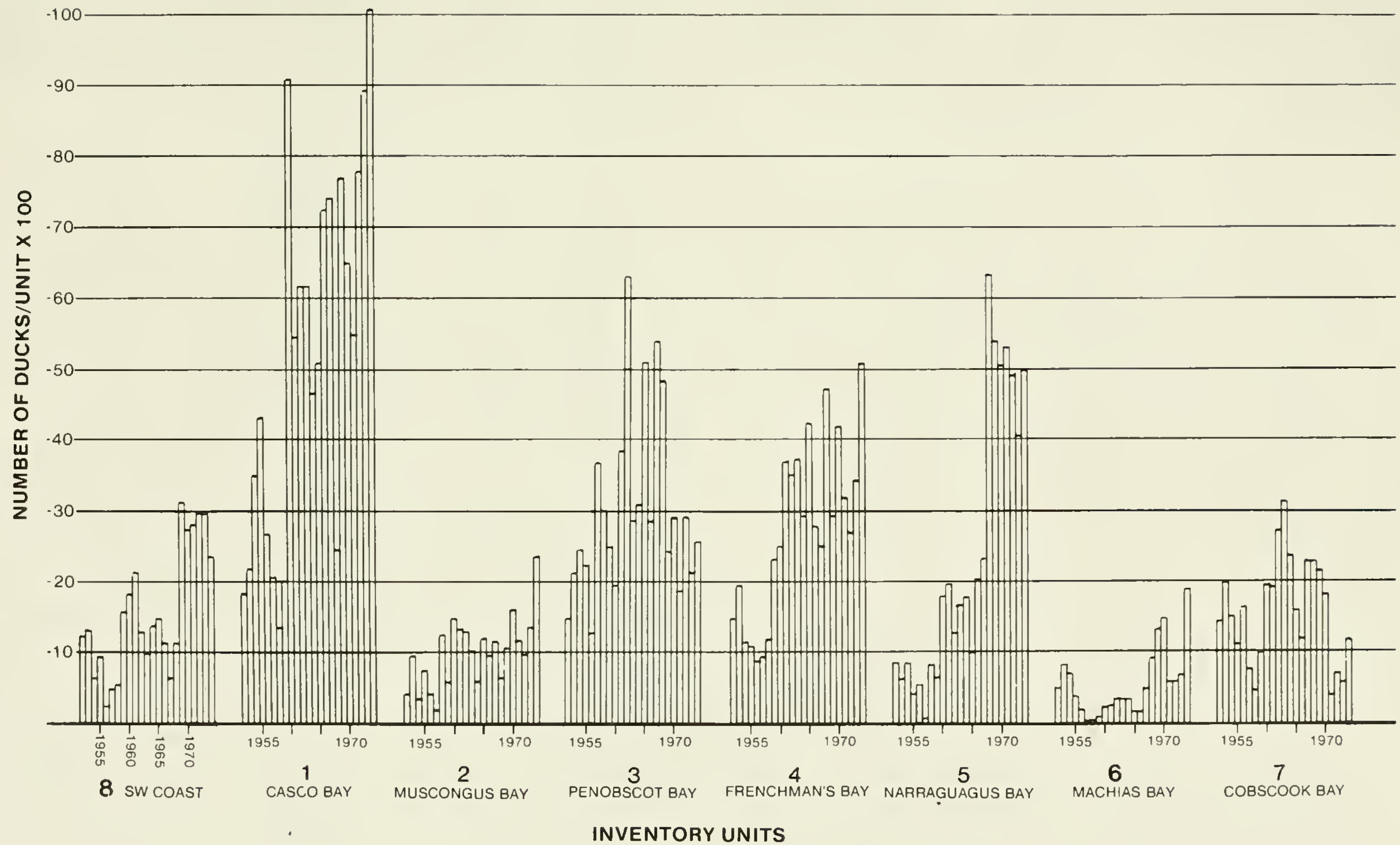

Figure 15-4. Estimated numbers (x 100) of wintering black ducks among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

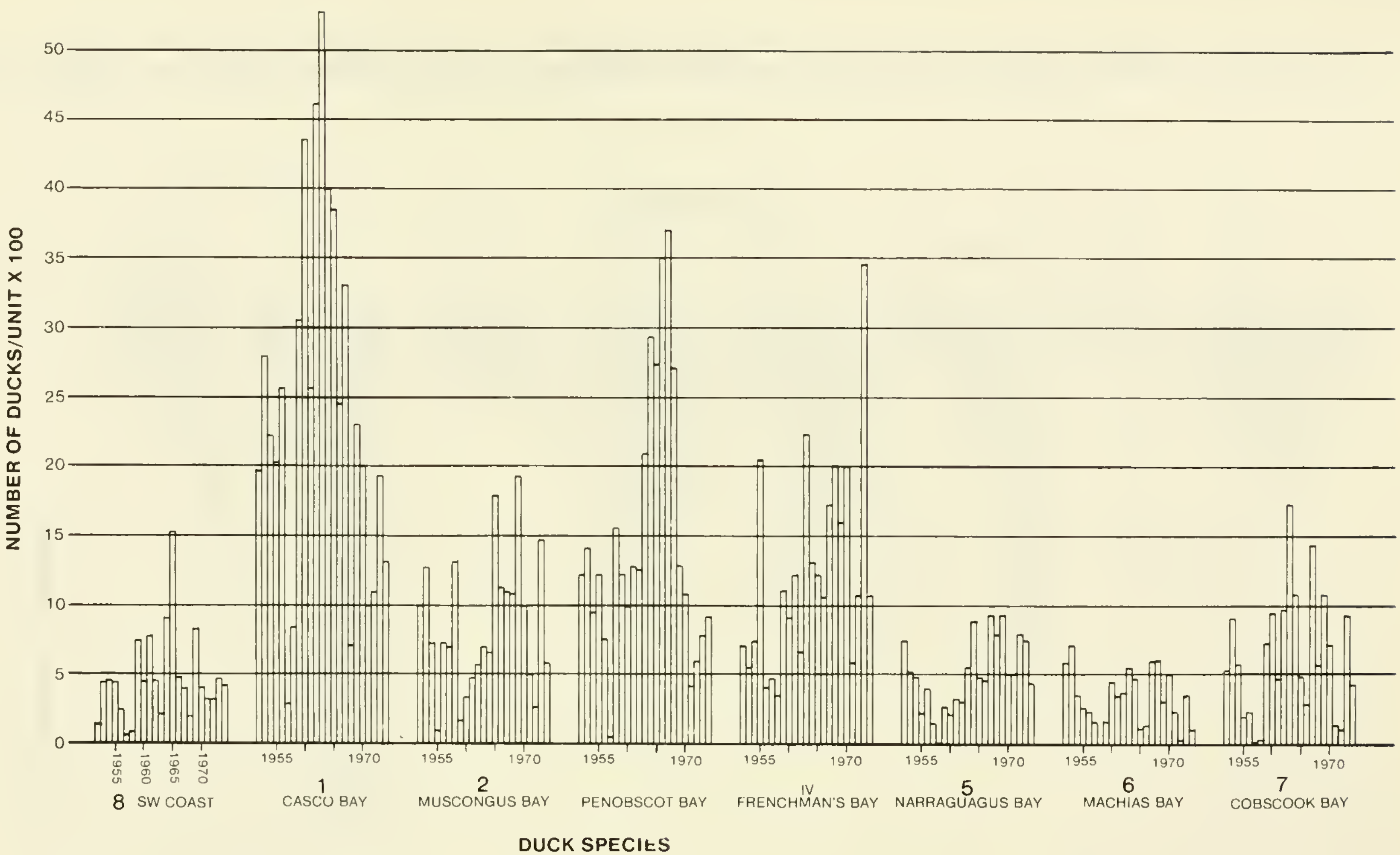

Figure 15-5. Estimated number (x 100) of wintering goldeneyes among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

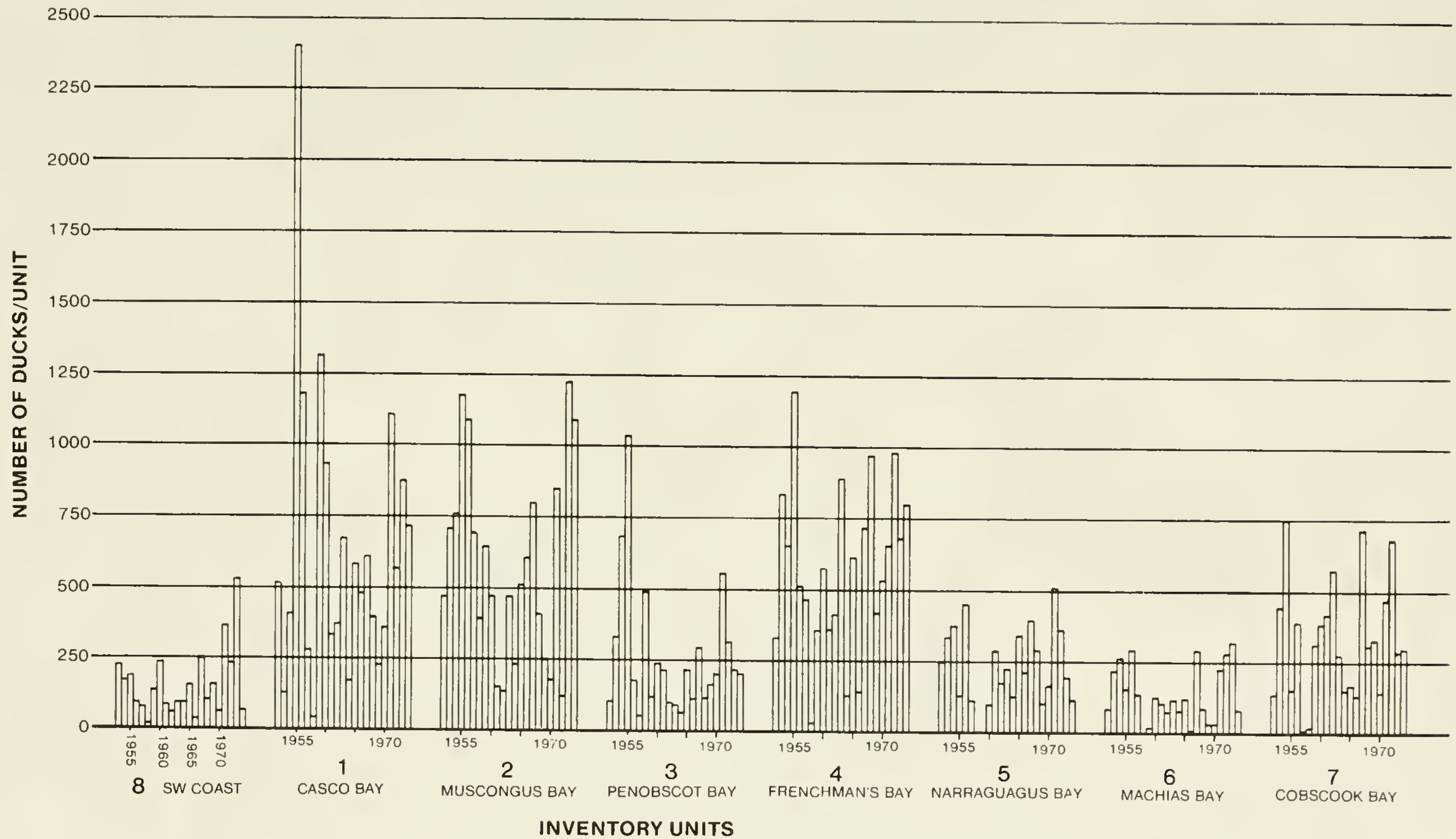

Figure 15-6. Estimated number of wintering buffleheads among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

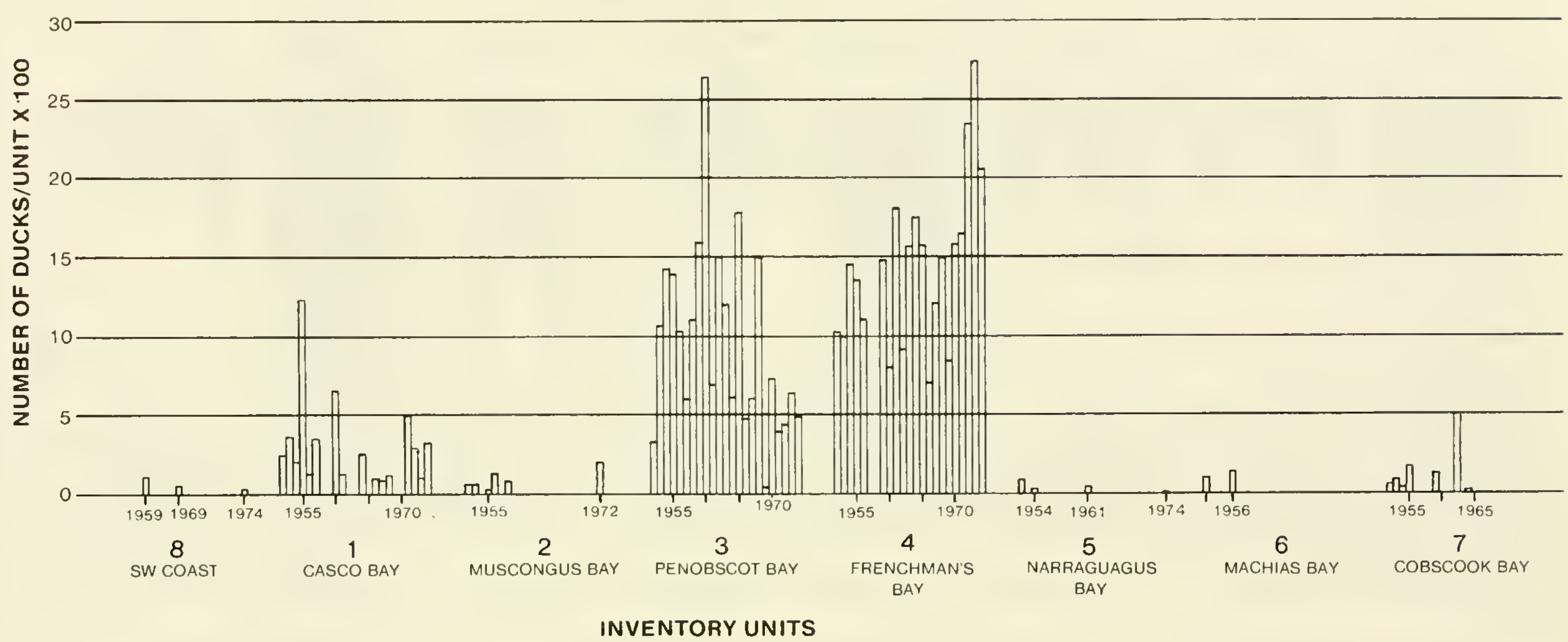

Figure 15-7. Estimated numbers (x 100) of wintering scaups among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

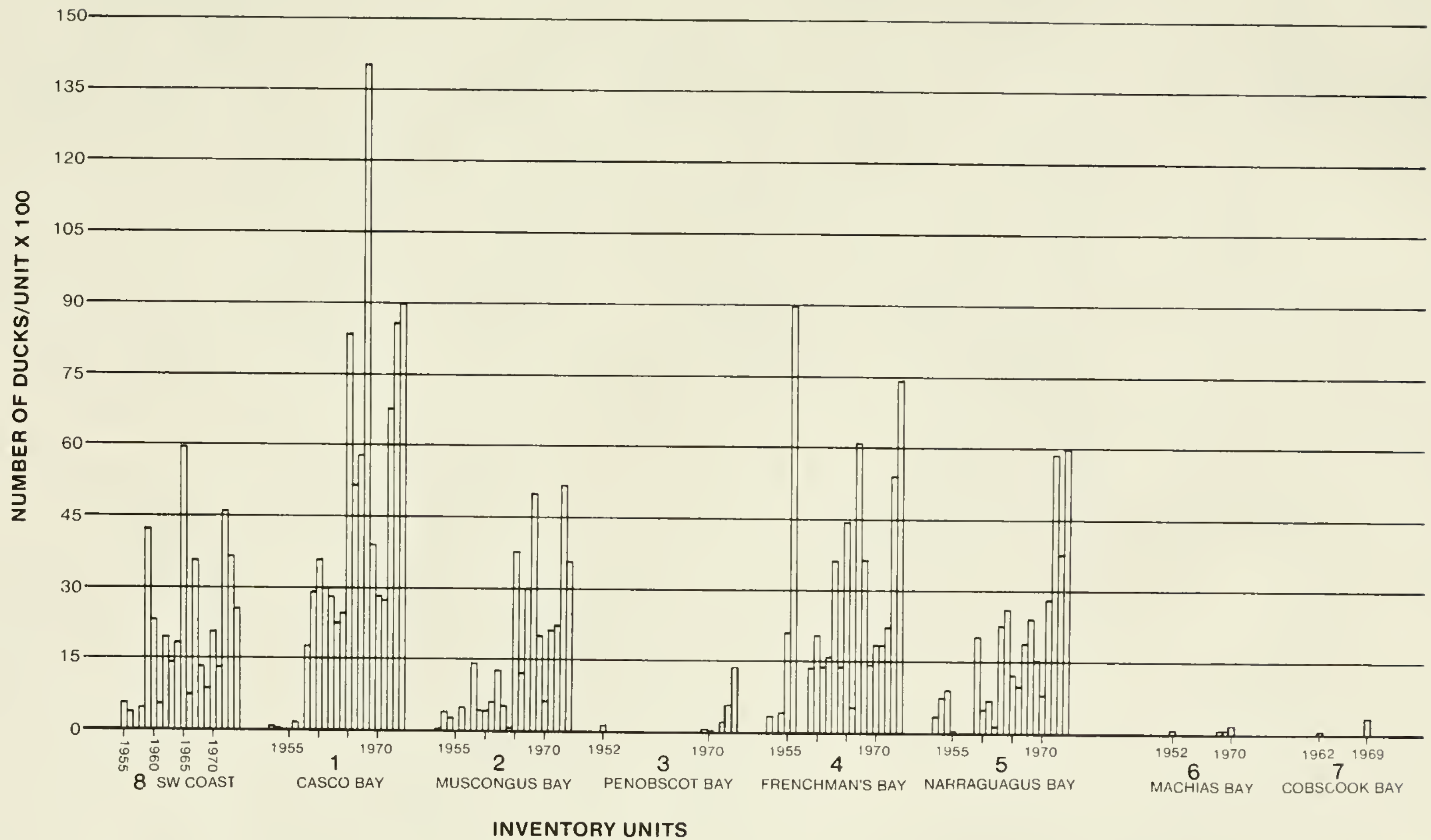

Figure 15-8. Estimated number (x 100) of wintering eiders among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

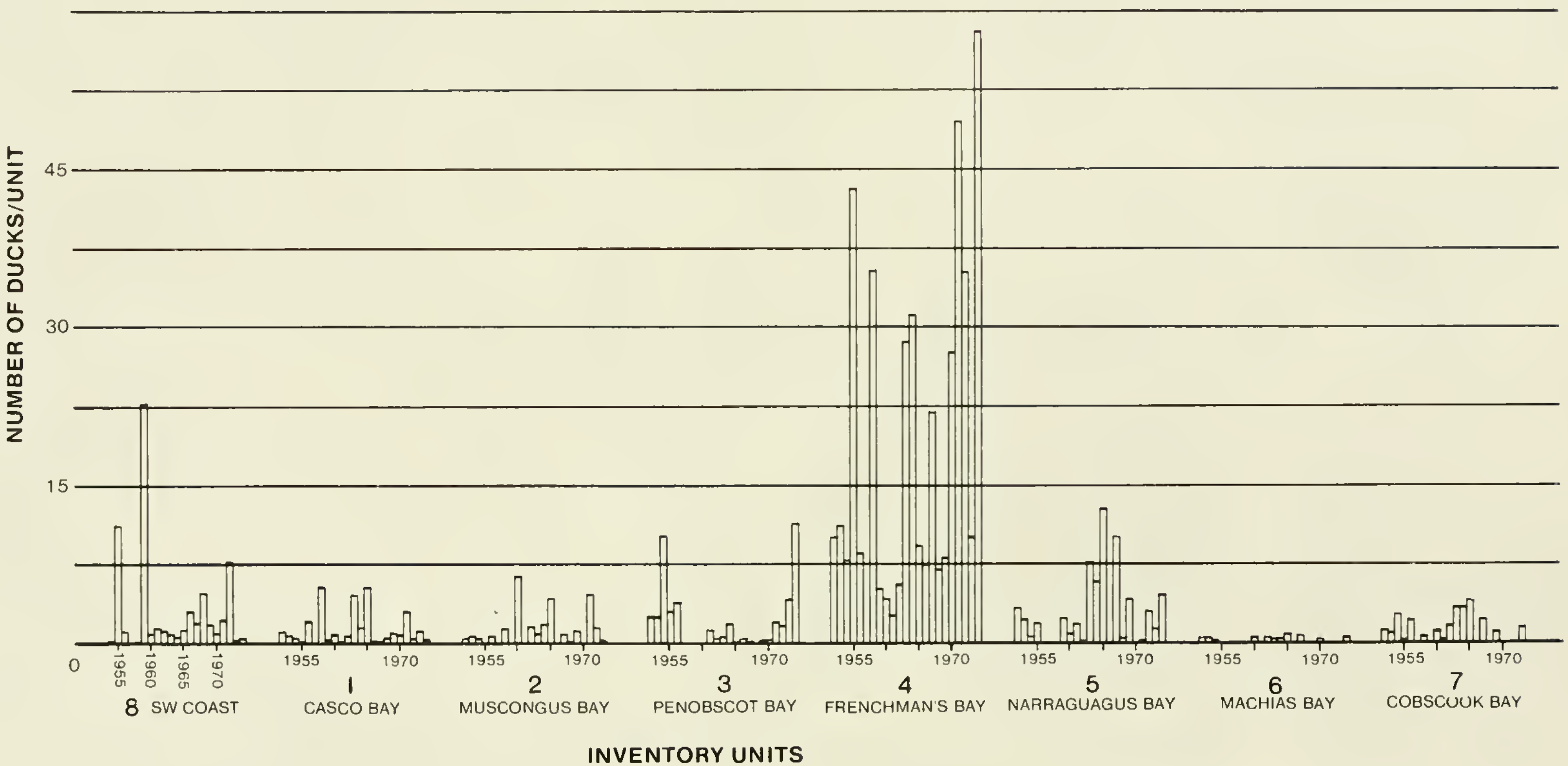

Figure 15-9. Estimated number (x 100) of wintering scoters among the winter waterfowl inventory units of coastal Maine for each year, 1952 to 1974.

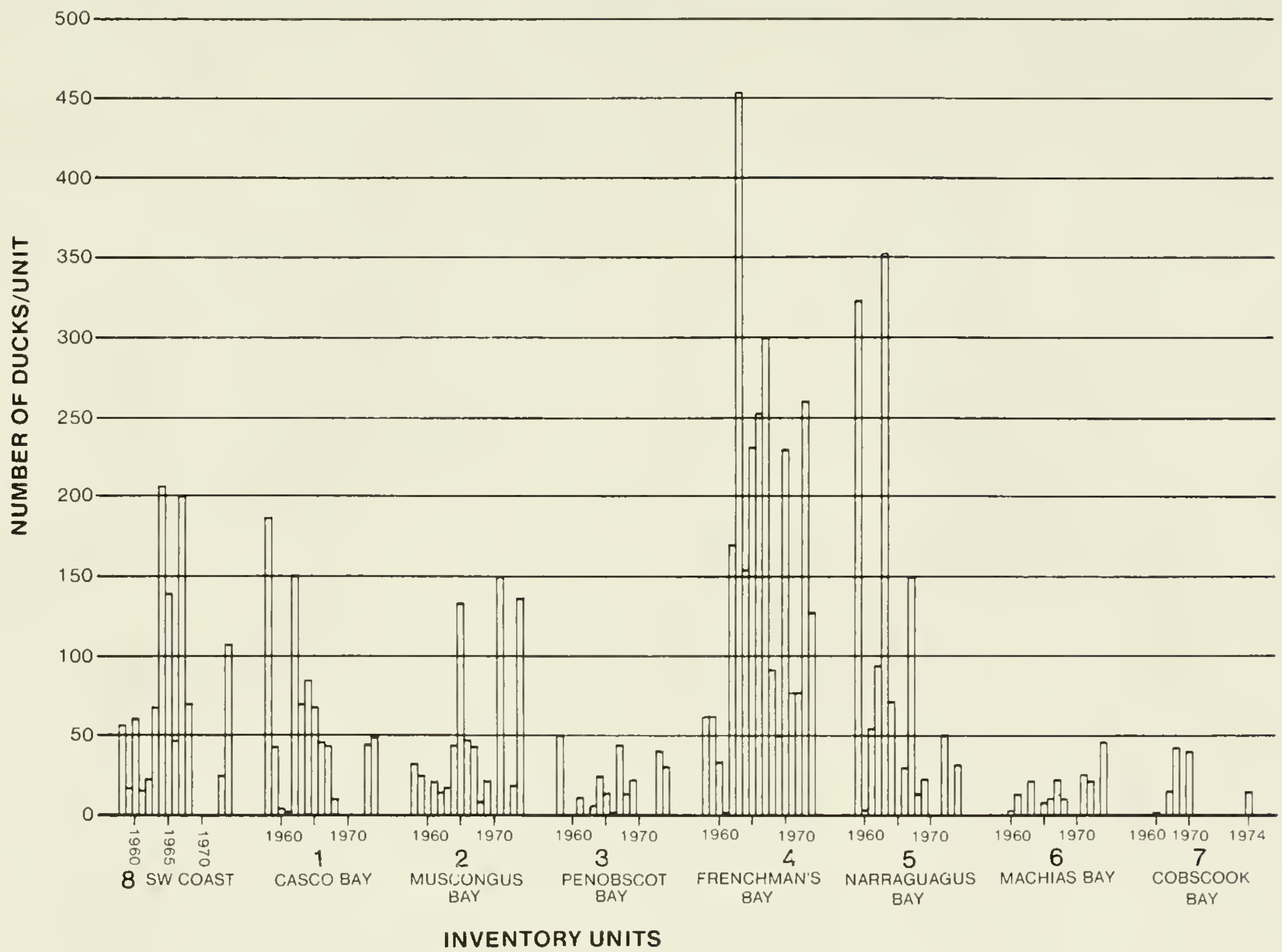

Figure 15-10. Estimated numbers of wintering old squaws among the winter waterfowl inventory units of coastal Maine for each year, 1958 to 1974.

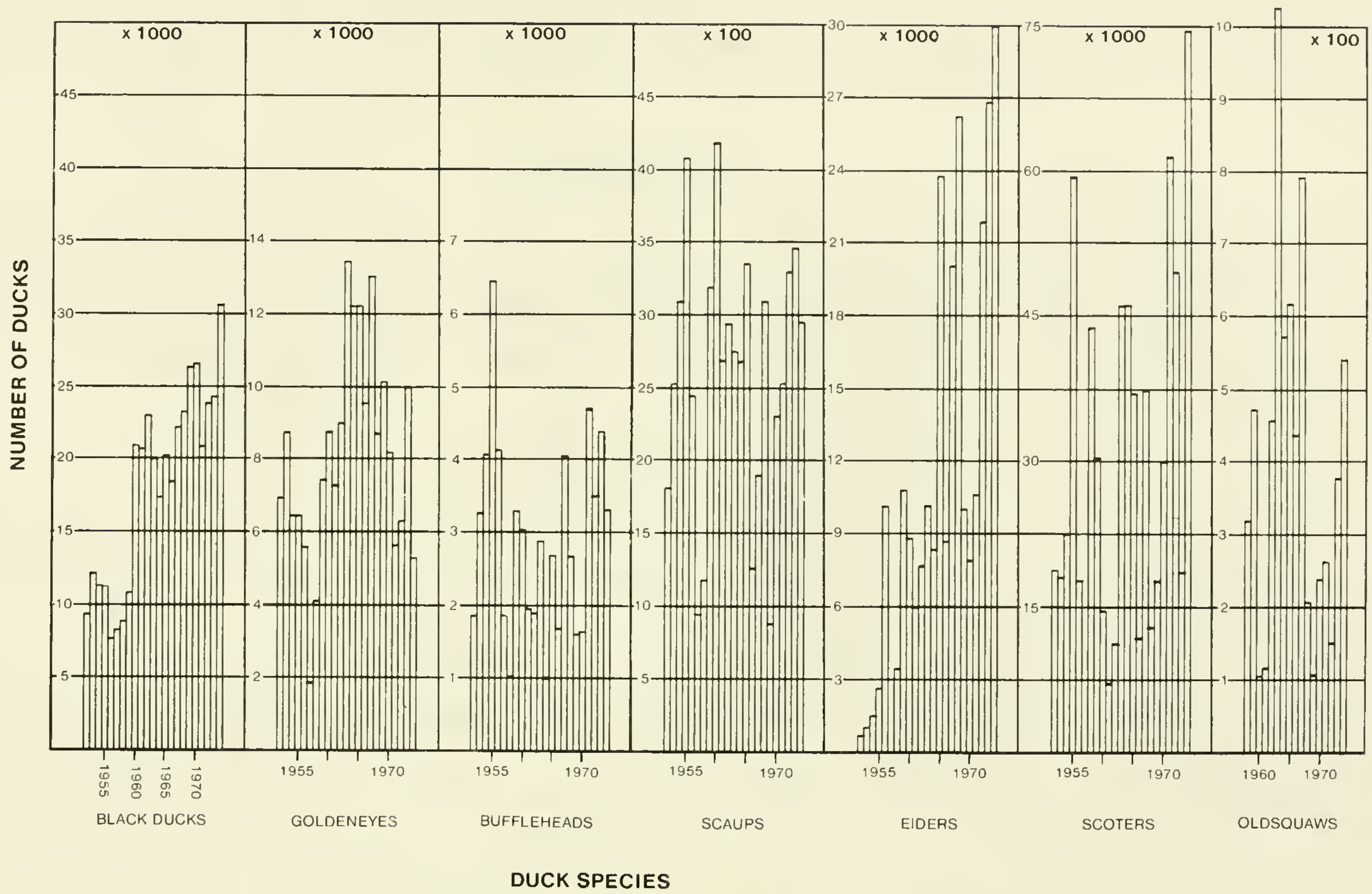

Figure 15-11. Estimated numbers (x 1000) of wintering ducks for coastal Maine for each year, 1952 to 1974.

Table 15-6. The Percentage Composition of Breeding Waterfowl Species, Based on Brood Counts, in Each Wildlife Management Unit (6 to 8), for the Units Combined, and Their Percentage Contribution to State Totals as Compiled from Maine Department of Inland Fisheries and Wildlife data from 1956 to 1965 and 1966 to 1976.

Species	WMU			Combined units 6 to 8	Statewide
	6	7	8		
1956 to 1965					
Black duck	38	53	62	48	44
Ring-necked duck	36	15	2	21	17
Wood duck	21	17	32	21	20
Goldeneye	-	tr	-	tr	8
Hooded merganser	4	3	-	3	8
Blue-winged teal	1	12	4	6	3
Common meganser	tr	-	-	tr	tr
Mallard	-	-	-	-	tr
Percentage of State Total	13	17	9	39	100
1966 to 1976					
Black duck	25	24	57	26	29
Ring-necked duck	64	36	4	44	25
Wood duck	4	15	3	12	12
Goldeneye	-	5	4	3	18
Hooded merganser	6	2	11	4	8
Blue-winged teal	1	19	-	11	4
Common merganser	-	-	-	-	3
Mallard	-	-	-	-	tr
Percentage of State Total	12	18	2	32	100

Table 15-7. Average Number of Broods of Ducks Per Acre Per Year in Different Wetland Types for Each Wildlife Management Unit (6 to 8) from 1956 to 1965 and 1966 to 1976.

Wetland Type[a]	Wildlife Mgt. Unit 6	Wildlife Mgt. Unit 7	Wildlife Mgt. Unit 8	Units 6-8 Combined	All units (1-8) Statewide
1956 to 1965					
2 Fresh meadows	-	0.61	1.91	0.85	0.27
3 Shallow fresh meadow	-	0.45	1.53	0.54	0.15
4 Deep fresh marsh	1.08	0.74	0.46	0.66	0.30
5 Open water	0.33	0.52	0.58	0.38	0.31
6 Shrub swamp	0.73	0.60	1.07	0.67	0.18
7 Wooded swamp	-	0.54	-	0.53	0.75
8 Bog	-	-	0.17	0.17	0.10
Average	0.37	0.50	0.58	0.46	0.21
1966 to 1976					
2 Fresh meadows	-	-	-	-	-
3 Shallow fresh marsh	-	0.53	0.90	0.57	0.12
4 Deep fresh marsh	3.34	2.24	-	2.63	0.14
5 Open water	0.23	-	-	0.23	0.14
6 Shrub swamp	-	0.42	-	0.41	0.13
7 Wooded swamp	-	-	0.20	0.20	0.48
8 Bog	-	-	-	-	4.29
Average	0.28	0.59	0.81	0.43	0.13

[a] Wetland types after Shaw and Fredine (1956) and McCall (1972); see table 15-9 for National Wetland Inventory equivalents.

Table 15-8. Acres and Numbers (in parentheses) of Different Wetland Types for Wildlife Management Units 6 to 8 and Contribution to the State Total (adapted from Maine Department of Inland Fisheries and Wildlife Wetland Inventory Files).

Wetland type	Wildlife Mgt. Units 6	Wildlife Mgt. Units 7	Wildlife Mgt. Units 8	Units 6-8	Percentage of State Total	State total
2 Fresh meadow	5757 (90)	5539 (77)	6467 (97)	17,763 (264)	31 (20)	57,683 (1273)
3 Shallow fresh marsh	3775 (52)	4738 (63)	2379 (74)	10,892 (189)	47 (50)	22,956 (381)
4 Deep fresh marsh	1819 (32)	3581 (51)	4008 (128)	9408 (211)	36 (52)	25,901 (404)
5 Open water	81,651 (256)	63,493 (209)	96,869 (312)	240,013 (777)	23 (25)	1,047,578 (3123)
6 Shrub swamp	11,493 (205)	12,658 (174)	12,386 (301)	36,537 (680)	17 (12)	210,513 (5779)
7 Wooded swamp	4080 (79)	8660 (129)	5322 (98)	18,062 (306)	6 (6)	293,727 (4611)
8 Bog	9257 (138)	3408 (33)	5921 (79)	18,586 (250)	11 (11)	166,324 (2257)
TOTAL	117,832 (852)	102,077 (736)	133,352 (1089)	353,261 (2677)	19 (15)	1,824,682 (17,828)

[a] Wetland types from Shaw and Fredine (1956) and McCall (1972); see table 15-9 for National Wetland Inventory equivalents.

On the basis of table 15-7, duck broods from 1956 to 1965 were most abundant in fresh meadows (1.91 in Wildlife Managment Unit 8, and an average of 0.85 in the three Wildlife Management Units combined). Duck broods were most abundant in deep fresh marshes from 1966 to 1976 (3.34 in unit 6, 2.24 in unit 7, 0.81 in unit 8, and 2.63 for the three units combined), but no breed counts were made in fresh meadows during that period. Abundance declined slightly from 0.46 to 0.43 for the three regions in the two time periods, and Statewide averages declined from 0.21 to 0.13. Causes for these differences are unknown. An average of 5 ducklings fledged per brood was estimated for waterfowl. This estimate is considered to be conservative, generally constant from year to year, and somewhat higher than for the eider.

The waterfowl breeding habitat by wetland type for the coastal units, and the Statewide acreage and number of areas are summarized in table 15-8. Table 15-9 compares the National Wetlands Inventory Classification scheme with the wetland types identified by the MDIFW. Brood abundance from 1966 to 1976 is used to calculate estimated annual brood production (table 15-7). The data indicate that 64% of the annual brood production of Maine (exclusive of eiders) is in the coastal units. The coastal Wildlife Management Units produced an average of 67,500 ducklings (exclusive of eiders) annually from 1966 to 1976. No known major changes have occurred since. Further extrapolation of these data would probably be subject to considerable error.

The fledging survival for eiders is difficult to determine due to their creching behavior (broods combine and are reared by a female) and because brood rearing takes place in open coastal waters, usually adjacent to islands. The smaller clutch size of the eider (4 to 6 eggs) plus the exposure of newly hatched ducklings to gull predation and other hazards of the coastal environment suggest fewer than 4 ducklings per brood live to the flight stage. Assuming 3 fledglings for the 11,500 broods, an estimate of 34,500 young eiders survived.

Migration and Staging Areas

Migratory waterfowl tend to concentrate at certain locations and exhibit relatively strong habitat preferences. Most of the southerly migration takes place in August through November. Some stay a few days, others remain for a month or two. It is characteristic of the dabblers (black ducks, mallards, wood ducks, green-winged teals, and blue-winged teals) to concentrate in relatively protected areas near an abundance of food. These are called staging areas. Migratory waterfowl in the fall are frequently composed of a high percentage of young birds (only a few months old).

Merrymeeting Bay in region 2 is one of the largest staging areas in the northeast Atlantic. Each autumn and spring this bay supports up to 40,000 waterfowl at one time. Concentrations begin to build in mid-August and last until the hunters or weather sends them southward. Black ducks and green-winged and blue-winged teal are most common but a number of other waterfowl species have been recorded, including the fulvous whistling duck. The attractiveness of Merrymeeting Bay to waterfowl is due to the remarkable abundance of high quality aquatic vegetation. Among the latter, wild rice (*Zizania aquatica*) is of prime importance.

Table 15-9. Comparison of the National Wetlands Inventory Classification and Circular 39 Wetland Types Used in the Maine State Wetland Inventory

Circular 39 types	NWI wetland and deepwater habitats		
	Classes	Water regimes	Water chemistry
Type 1—Seasonally flooded basins or flats Wet meadow (Dix and Smeins 1967; Stewart and Kantrud 1972) Bottomland hardwoods (Braun 1950) Shallow-freshwater swamps (Penfound 1952)	Emergent Wetland Forested Wetland	Temporarily Flooded Intermittently Flooded	Fresh Mixosaline
Type 2—Inland fresh meadows Fen (Heinselman 1963) Fen, northern sedge meadow (Curtis 1959)	Emergent Wetland	Saturated	Fresh Mixosaline
Type 3—Inland shallow fresh marshes Shallow marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland	Semipermanently Flooded Seasonally Flooded	Fresh Mixosaline
Type 4—Inland deep fresh marshes Deep marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland Aquatic Bed	Permanently Flooded Intermittently Exposed Semipermanently Flooded	Fresh Mixosaline
Type 5—Inland open fresh water Open water (Golet and Larson 1974) Submerged aquatic (Curtis 1959)	Aquatic Bed Unconsolidated Bottom	Permanently Flooded Intermittently Exposed	Fresh Mixosaline
Type 6—Shrub swamps Shrub swamp (Golet and Larson 1974) Shrub-carr, alder thicket (Curtis 1959)	Scrub-Shrub Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 7—Wooded swamps Wooded swamp (Golet and Larson 1974) Swamps (Penfound 1952; Heinselman 1963)	Forested Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 8—Bogs Bog (Dansereau and Segadas-vianna 1952; Heinselman 1963) Pocosin (Penfound 1952; Kologiski 1977)	Scrub-Shrub Wetland Forested Wetland Moss-Lichen Wetland	Saturated	Fresh (acid only)
Type 9—Inland saline flats Intermittent alkali zone (Stewart and Kantrud 1972)	Unconsolidated Shore	Seasonally Flooded Intermittently Flooded Temporarily Flooded	Eusaline Hypersaline
Type 10—Inland saline marshes Inland salt marshes (Ungar 1974)	Emergent Wetland	Seasonally Flooded Semipermanently Flooded	Eusaline
Type 11—Inland open saline water Inland saline lake community (Ungar 1974)	Unconsolidated Bottom	Permanently Flooded Intermittently Flooded	Eusaline
Type 12—Coastal shallow fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Irregularly Flooded Semipermanently Flooded-Tidal	Mixohaline Fresh

(Continued)

Table 15-9. (Concluded)

Circular 39 types	NWI wetland and deepwater habitats		
	Classes	Water regimes	Water chemistry
Type 13—Coastal deep fresh marshes			
Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Semipermanently Flooded-Tidal	Mixohaline Fresh
Type 14—Coastal open fresh water			
Estuarine bays (Stewart 1962)	Aquatic Bed Unconsolidated Bottom	Subtidal Permanently Flooded-Tidal	Mixohaline Fresh
Type 15—Coastal salt flats			
Panne, slough marsh (Redfield 1972) Marsh pans (Pestrong 1965)	Unconsolidated Shore	Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline
Type 16—Coastal salt meadows			
Salt marsh (Redfield 1972; Chapman 1974)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline
Type 17—Irregularly flooded salt marshes			
Salt marsh (Chapman 1974) Saline, brackish, and intermediate marsh (Eleuterius 1972)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline
Type 18—Regularly flooded salt marshes			
Salt marsh (Chapman 1974)	Emergent Wetland	Regularly Flooded	Euhaline Mixohaline
Type 19—Sounds and bays			
Kelp beds, temperate grass flats (Phillips 1974) Tropical marine meadows (Odum 1974) Eelgrass beds (Akins and Jefferson 1973; Eleuterius 1973)	Unconsolidated Bottom Aquatic Bed Flat	Subtidal Irregularly Exposed Regularly Flooded Irregularly Flooded	Euhaline Mixohaline
Type 20—Mangrove swamps			
Mangrove swamps (Walsh 1974) Mangrove swamp systems (Kuenzler 1974) Mangrove (Chapman 1976)	Scrub-Shrub Wetland Forested Wetland	Irregularly Exposed Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline Mixohaline Fresh

In the spring, Merrymeeting Bay is a stopping place for thousands of northward moving Canada geese and ducks. They begin to arrive in mid-March and some remain through mid-May. Apparently these birds feed on plants carried over from the previous growing season as well as new growth. Merrymeeting Bay is a highly important area that should be preserved and intensively managed for waterfowl and other natural resources. It has been studied and investigated by various individuals and agencies and for an in-depth review and discussion refer to Reed and D'Andrea (1973).

In addition to Merrymeeting Bay, various other estuaries, bays, and inlets along the coast are valuable as nesting and feeding areas for migrating and wintering waterfowl. Inland palustrine, lacustrine, and riverine systems are used by migrating ducks and geese. The distribution and nature of these habitats are reviewed in the following section.

Waterfowl Habitat

Depending on the species, season, weather, or purpose of use, the waterfowl of coastal Maine utilize all of the wetland types. Breeding ducks usually avoid areas affected by strong tides and favor the freshwater wetlands. Migrants seem to prefer coastal marshes and open waters, and wintering birds favor sounds, bays, and tidal flats. Wetlands designated as important to waterfowl are presented in atlas map 4.

Waterfowl largely use habitats that provide their preferred foods. The exception is in winter when ice cover strongly effects their distribution. Various studies indicate food habits vary among species, age groups, and season (Mendall 1949; Martin et al. 1951; and Reinecke 1977). Breeding game ducks and their newly hatched ducklings depend largely on invertebrates for food. After 6 weeks of age the young tend to feed more on vegetative foods. In the fall, vegetation is heavily used by inland waterfowl populations, whereas invertebrates dominate in the estuarine and marine systems. Eelgrass (*Zostera marina*) is the only true marine vegetable food of sufficient quality and abundance along the Maine coast to be a major food for ducks. In general, waterfowl in marine waters feed largely on eelgrass and invertebrates (bottom organisms) in the fall, winter, and early spring.

Region 1. This region has less inland waterfowl nesting habitat than any of the other regions but supports more wintering waterfowl because of its high quality marine littoral zone. Most areas are feeding grounds for migrating and wintering birds (table 15-5). There is an abundance of waterfowl food nearshore along the coast and nearby coastal islands, and in some estuarine areas where there are extensive tidal flats, mussel bars, and eelgrass beds. Eiders nest on certain islands in this and all other regions (see chapter 14, "Waterbirds").

In average winters marine habitats adjacent to islands provide ice-free feeding grounds for waterfowl when inshore bays and tidal marshes are frozen (this applies to all regions). The many ledges and bars associated with the outer islands of Casco Bay are also important wintering areas for scoters, eiders, and old squaw ducks. These same areas are used by migratory brant in spring.

Region 2. This region has a greater proportion of palustrine, riverine tidal, and estuarine emergent wetlands than any of the other regions. It includes the estuaries of three major rivers; the Kennebec, Androscoggin, and Sheepscot. This region also includes Merrymeeting Bay, where the largest concentrations of waterfowl are found.

Region 2 is similar to region 1 because the ice cover in estuaries forces wintering or migrating waterfowl to use the areas adjacent to the many islands for feeding and protection. Major species are sea ducks, i.e., eiders, scoters, and old squaw ducks, which tend to winter as near shoreward as ice permits.

The Maine Yankee Atomic Power Plant is located within this region adjacent to the Sheepscot estuary at Wiscasset. To date this plant, or its construction and wastes, have had no measurable effect on habitat utilization by waterfowl (Spencer 1974). The non-tidal wetlands of this region are numerous and highly productive for breeding waterfowl (table 15-6) as well as for spring and fall migrants.

Region 3. This region encompasses the coast from Boothbay to Port Clyde and includes the Damariscotta, Medomak, and St. George River estuaries, and Muscongus Bay. The nearshore marine waters are important to wintering and migrating sea ducks (scoters, eiders, and old squaw ducks), and to breeding eiders. The estuaries are heavily utilized in fall, winter, and spring by black ducks, goldeneyes, and buffleheads. The Medomak estuary, particularly from 1960 to 1975, supported a large population of black ducks. Although there has been a drastic unexplained decline since 1975, similar but less drastic declines occurred in other areas of Maine. There also was a slight decline in wintering goldeneyes and buffleheads. Available evidence suggests a combination of factors were responsible for these declines. The possibility of habitat change in the estuarine system cannot be discounted entirely. Here, as in other parts of the coast, casual observations by several observers indicated a reduction of the density and abundance of eelgrass may have taken place. The last survey of the eelgrass beds was made around 1969. The interaction of eelgrass and black ducks, and other Maine wintering waterfowl, needs to be better understood and represents an obvious data gap.

Population changes in the St. George River estuary have not been as great as in the Medomak estuary (Maine Department of Inland Fisheries and Wildlife survey data). Comparable data for the Damariscotta estuary are lacking, but in the case of the St. George estuary eelgrass has not been abundant at any time in the past two decades. A future concern in this region is the preservation and management of island nesting habitat for eiders.

Region 4. This region largely is represented by the Penobscot Bay estuary. It has a large variety of wetland and marine habitat and is the center of breeding eider colonies. As in region 3, management of these nesting islands is of prime concern. Of particular importance to breeding eiders, and all wintering sea ducks, are the islands of the Muscle Ridge group; Isleboro, Deer Isle, North Haven-Vinalhaven, and Isle au Haut complexes. The southeastern end of Isle au Haut is a wintering area for harlequin ducks.

Among the lesser estuaries, two (Weskeag River and Marsh Stream) are characterized by sizeable (for Maine) tidal marshes. Major portions of these two wetlands are owned and managed by the MDIFW to benefit watefowl and other wildlife. Principle waterfowl species utilizing these marshes are black ducks, goldeneyes, buffleheads, and Canada geese. Most intensive use occurs during spring and fall migration periods. The estuaries of the Penobscot, Orland, and Bagaduce Rivers traditionally have been prime wintering and migration areas for black ducks, goldeneyes, buffleheads, and limited numbers of greater scaup. During winter, all of these estuaries freeze progressively further seaward, and from shore to center channel. The Orland and Bagaduce Rivers may freeze almost completely, and the main stem of the Penobscot River frequently requires ice-breakers to clear the way for passage above Bucksport (see chapter 2, "The Maine Coast Ecosystem"). During intense cold, tidal flats usually freeze during the ebb tide and the flood tide tempertures are insufficiently high to thaw them between tides. When the flats are frozen, the black duck and other dabblers are forced into a narrow band between the low water mark and the maximum feeding depth (24 inches; 61 km). Although food may be abundant and readily available in the vicinity of an island 5 to 10 miles (8 to 16 km) seaward, black ducks remain in their traditional wintering habitats even if starvation threatens.

The Bagaduce estuary, noted for its lush and extensive eelgrass beds, has not shown a winter decline in duck abundance. This estuary, and the Penobscot and Orland estuaries in region 4, have not experienced major declines in wintering birds since 1976 (MDIFW file data). These eelgrass beds in region 4 also provide food for a flock of wintering Canada geese.

Region 5. The Narraguagus River is the largest in this region but is long, narrow, and little used by waterfowl. Narraguagus Bay, with its highly irregular shoreline, extensive intertidal flats, and many islands, is excellent marine wintering and migration habitat for black ducks, goldeneyes, buffleheads, scoters, eiders, and old squaws. Region 5 is about the eastern limit of significant eider wintering and molting areas. The marine waterfowl environment of this region is characterized by many small, shallow, and well protected bays with large acreages of intertidal flat feeding areas. Excellent beds of eelgrass are known in some areas west of Schoodic Point, in the Mt. Desert Island Narrows, Goose Cove, and Taunton Bay. Smaller, more sparse, stands occur in other nearby areas.

The Frenchman's Bay area is the most important wintering area for greater scaup on the entire coast. Several small tidal rivers empty into Frenchman's Bay and are important to other wintering and/or migrating waterfowl. From west to east these include: the Jordan River, Trenton; Skillings River, Lamoine; and the Taunton River, Sullivan.

East of Schoodic Point, Gouldsboro Bay, Dyer Bay, Pigeon Hill Bay, Back Bay, Flat Bay, Harrington River Estuary, and the Pleasant River Estuary are all important for wintering and migratory waterfowl.

Region 6. This northeastern most region stretches from the western boundary at Addison, to Calais, to the head of tide on the St. Croix River estuary. From the Addison boundary to Cutler Harbor the coastline is highly irregular with many bays, coves, islands, and tidal stream estuaries. It is excellent habitat for all migrating and wintering waterfowl species of Maine although scaup seldom occur in significant numbers. The increased tidal range in this region results in very extensive flats that provide thousands of acres of feeding grounds for black ducks. Presumably, invertebrate foods are abundant and black duck populations utilizing the Machias and Cobscook Bay units have not declined recently as have populations farther southwest. No extensive eelgrass beds have been observed during low altitude flights over the area at low tide. Generally the intertidal flat habitat is heavily utilized by black ducks irrespective of ice conditions.

Wintering eiders are not commonly observed east of Beals Island. The most recent 5-year average count for eiders in the Machias Bay unit (table 15-5) was only 32, and none for Cobscook Bay.

The coast from Cutler Harbor to Lubec is bold, rock-bound, and, for Maine, fairly regular. Waterfowl are not numerous along this stretch. In contrast, the vast tidal flat between West Quoddy Head and Lubec, in additon to being a general feeding area for many species of waterfowl and shorebirds, is one of the few important stopovers for migrating brant. More than 5000 have been estimated at times during the spring migration (personal communication from M. A. Redmond, Lubec, Maine; February, 1979). From West Quoddy Head upriver, throughout Cobscook Bay and northward to Calais, tides may reach or exceed 20 feet (6 m; 22.8 ft., or 7 m, at Calais). Within this area, the Cobscook Bay complex of inlets, tidal creeks, and rivers, plus strong tidal flows and rich invertebrate fauna, create many acres of excellent wintering and migration habitat for waterfowl. Scoters and old squaws frequent the deeper areas and mussel bars, and goldeneyes, buffleheads, and black ducks utilize the shallower areas and intertidal flats. Cobscook Bay has not experienced the recent decline in wintering black duck numbers. Because of the strong tidal flow, winter ice conditions are seldom as severe in region 6 as in regions 1 to 5.

Although waterfowl density in inland waters is not as high in region 6 as it is farther southwest, it is still high particulary for ring-necked ducks. The low density human populations and lack of human development compared to the rest of the coast, contribute further to the region's value as a natural area.

Ecological Interactions

Many ecological interactions take place among waterfowl, especially those related to food and feeding habits. Breeding waterfowl, especially pre- and post-nesting females and young up to about 6 weeks of age, tend to feed heavily on invertebrate foods. The tendency towards eating plant food is strongest in late summer and fall. This is notably true for the black duck, wood duck, and blue-winged teal (Drobney 1977; and Swanson et al. 1977). What effect feeding waterfowl may have on the abundance and distribution of invertebrates (bottom dwelling forms) or on aquatic vegetation in Maine is not known, but any changes are likely to be highly localized. An example is the eider duck which sometimes depletes cultured oyster beds in the central coastal area (personal communication from G. G. Donovan, Maine Department of Inland Fisheries and Wildlife, Augusta, ME.; August, 1977). Blue mussels sometimes are eaten in abundance by eiders and scoters.

A high abundance of toxin-producing dinoflagellates (Gonyaulus excavata), red tide organism, and their assimilation and accumulation in the fleshy tissues of mussels and clams, has caused considerable public concern in Maine. A very limited collection of eiders (<20 birds) feeding in an area where mussels were highly toxic, revealed the birds had been feeding largely on nontoxic crabs and eider tissues contained very low concentrations of the toxin (personal communication from G. G. Donovan, Maine Department of Inland Fisheries and Wildlife, Augusta, ME.; August, 1977). The relation of the red tide organisms to waterfowl needs further investigation.

The mergansers, with the possible exception of the hooded merganser, are primarily fish eaters. Although not abundant breeders in coastal Maine, the common merganser may be a troublesome predator on juvenile salmonids in rivers and ponds (Munro and Clemens 1937; and Elson 1962).

A winter food relationship among eels, common mergansers, and bald eagles has been established in the rivers and estuaries of coastal Maine. According to studies by R. B. Owens, Jr. (personal communication, School of Forest Resource, University of Maine, Orono, ME.; February, 1979), the mergansers feed heavily on small eels, some of which might be heavily contaminated with heavy metals or pesticides. The contaminated mergansers are fed on by bald eagles which assimilate the contaminants in their body tissues. It is not known how serious this problem is in Maine (although heavy metal and pesticide residues are high in nonproductive eagle eggs), or how the contaminants affect mortality rates of wildlife or threaten human health.

Another interaction that has management implications is the competition for nest boxes. Erected for nesting wood ducks, goldeneys, and hooded mergansers, MDIFW studies (Spencer and Corr 1977) indicate as many as 10% of these occupied boxes may contain mixed clutches with two of the three species. In addition, American kestrels, tree swallows, starlings, bees, and hornets frequently use nest boxes, reducing the value of the boxes for tree-nesting ducks. Carefully selected sites, proven installation techniques, and regular maintenance greatly enhance their use by nesting ducks.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE

The many factors affecting the distribution and abundance of a species or group of species at various times and places are difficult to measure. Natural and human-made factors known to influence coastal waterfowl are described below.

Natural Factors

Natural factors influencing population size and distribution are disease, parasites, predation, quantity and quality of habitat, food supplies, and weather. The only disease troublesome to coastal Maine, primarily in the Penobscot Bay area, is fowl cholera (*Pasteurella multocida*) which afflicts nesting eider ducks (Gershman et al. 1964). Since its discovery in 1963 near Camden, it has reoccurred in several years but has not been widespread. Fowl cholera can cause the loss of nearly all adult females in a specific island nesting colony, but islands only a few miles away may escape the disease entirely. The disease does not appear to measurably reduce the breeding population coastwide. Annual monitoring of the disease's occurrence and sanitation operations, when necessary, is a continuing need.

Parasites may, at times, cause some waterfowl losses, but their overall effect is difficult to assess. The acanthocephalan, Polymorphus botulis, is common in the intestines of many Maine eiders and has caused local mortality (Grenquist 1970). Blood parasites in freshwater breeding areas are commonly transmitted to ducks by biting flies (Diptera). These include protozoan malaria-like parasites of the genera Leucocytozoon, Haemoproteus, and Plasmodium. O'Meara (1954) found an abundance of blood parasites in samples of central Maine waterfowl. Infections of Haemoproteus nettionis and Leucocytozoon simondi were found in more than 80% of a sample of Maine wood ducks collected on the Penobscot River between Old Town and Lincoln (Thul 1977); <1% were infected with Plasmodium circumflexum. Although these parasites are common among waterfowl, no evidence has been found that it leads to mortality. The debilitating effects of parasites probably reduce the resilience of waterfowl to disease or predation.

Predation is another natural mortality factor whose effects are difficult to measure. Predation alone is not known to materially reduce waterfowl populations in coastal Maine. The most serious predation affects nests, nesting adults, and/or young. Mammals that prey on eggs and ducks are raccoon, skunk, red fox, mink, weasels, bobcat, and perhaps coyotes. Significant avian predators are gulls, crows, and great-horned owls. Owls usually take adult and young ducks, whereas crows and gulls are essentially nest predators. Both the herring gull and the great black-backed gull regularly take ducklings. In some instances gull predation on a nesting colony of eider ducks may reduce breeding success and potential. The raccoon is the most serious predator on nest boxes. The snapping turtle is sometimes a significant predator on young ducks in freshwater habitats.

The distribution, size, and quality of aquatic habitats have a great influence on the abundance of coastal waterfowl. Waterfowl habitat was discussed earlier and is mentioned here only to recall some of the factors that may influence breeding or wintering populations.

Cavity-nesting waterfowl have the most specific nesting habitat requirements. Accordiing to Spencer and Corr (1977), wood ducks, hooded mergansers, and goldeneyes utilize a high proportion of artificial nest boxes in the central coastal area (regions 2 and 4, particularly). Populations of these species appear to have increased by well designed nest box programs. Whether this reflects a lack of adequate natural sites, a preference for boxes, or greater success in boxes, is unknown. It is probably safe to assume the artificial boxes are less subject to predation than natural sites.

The status of beaver populations also has a direct effect on the amount and quality of waterfowl breeding habitat. In fact, beaver impoundments may be the optimum habitat for black ducks, wood ducks, and hooded mergansers. Depending upon the nature of the individual flowage, blue-winged teal, green-winged teal, and ring-necked ducks also often utilize beaver ponds for nesting and brood rearing. Optimum beaver management is also good waterfowl management in Maine.

Tidal habitat for wintering and migrating birds is highly diverse and variable throughout coastal Maine. Winter-inventory data (MDIFW files) indicate drastic declines in the number of waterfowl (particularly black ducks) utilizing major tidal areas. Winter populations in the Kennebec River and the

Medomak River estuary (region 2) have declined sharply. This reduction may have been caused by changes in the availability of eelgrass either as a vegetable food or for the associated invertebrate fauna.

In the last decade there has been a significant reduction in pollution in the Penobscot and Kennebec estuaries. Whether the effect of cleaner water has been favorable or unfavorable to waterfowl populations using these areas is unknown.

Although food supplies are usually adequate in high quality waterfowl habitats, food supplies can change rapidly. Most inland Maine waters support only small quantities of vegetative duck foods. In riverine and/or lacustrine systems, sharp changes in water levels may alter food availability.

In some rivers, dams help reduce flooding and increase minimum flows which may help maintain an abundance of aquatic foods, especially for dabbling ducks.

Weather sometimes causes high duck mortality during the breeding season. Unusually low temperatures or heavy precipitation in late April, May, and June may cause heavy losses of nests or young ducklings, depending upon the nesting habits of the species. For example, black ducks (early nesters) are apt to be affected by floods in late April and May, whereas ring-necked ducks (late nesters) are more susceptible in June.

Cold, wet weather during nesting sometimes causes high brood mortality at a time in the breeding season when it is too late for renesting. Extreme weather during migration might either prolong or hasten movement in spring or fall. Early winter weather seems to affect black ducks and geese most by icing their feeding grounds (usually mud flats). Low temperatures can severely restrict black duck food availability. Black duck losses due to starvation are known to occur, but it is difficult to assess because of their habit of hiding and starving in a particular area even if food is available nearby.

Human Factors

Human-made changes in habitat sometimes adversely, and severely, affect waterfowl. Hunting and natural mortality have recently been shown to be in balance with recruitment up to a threshold level in mallards (Anderson and Burnham 1976), but what that level is for various waterfowl in Maine has not been defined. Annual variation in breeding success is the major factor causing variations in abundance.

Human activities may be beneficial or harmful. The intentional management of beaver and well conceived and executed nesting box programs favor some species of ducks, but intensive urban and suburban development of wetland shorelines, and recreation and boating activity may reduce waterfowl production locally. Because of human causes it is clear that in recent decades there has been a reduction in waterfowl habitat in many inland water areas of coastal Maine.

Although hunting mortality has been shown to be largely compensatory in relation to natural mortality, banding data reveal local breeding populations may be subjected to excessive kill in the fall before they disperse.

POTENTIAL IMPACTS OF HUMAN ACTIVITIES

Human developments described elsewhere in this report, and their potential impacts upon the environment, are listed in chapter 3. Some of the more important potential impacts on waterfowl are reviewed below.

Forestry Practices

Logging and cutting in coastal Maine forests affect waterfowl primarily by destroying breeding habitat. The abandonment of old logging dams in recent decades, and their subsequent deterioration, resulted in lower water levels in ponds and the drainage of others.

The use of pesticides for forest management in summer may destroy a major food source (largely adult or larval insects) for nesting females and young ducklings. Herbicides are currently being used as a means of improving forest stands by killing certain hardwoods. Clearcutting of hardwood forests, especially near streams and ponds, reduces the availability of nesting sites for cavity-nesting ducks.

Industrial or Urban Development

Land use changes occurring on or near wetlands causes degradation or loss of waterfowl habitat. Highway construction, housing, commerical construction, and summer recreation activities all take a toll. The development of recreation facilities and housing is one of the biggest threats to waterfowl in lacustrine systems.

Oil Pollution

Oil spills occurring in harbors, bays, and rivers could cause locally sever losses of waterfowl. Spills originating from shipping historically have been the most damaging in or near the port of Portland. Continued spills and waterfowl losses are expected, and if additional oil ports or refineries are developed, spills and waterfowl losses are likely to increase.

Tidal Power Development

The potential effect of the proposed tidal power facilities in the Cobscook Bay area (region 6) upon waterfowl is difficult to evaluate. Changes in the water regime could adversely affect the availability and quality of marine invertebrate foods for waterfowl. The potential effect of power development on mud flats, water levels, and ice formation has not been assessed. This developement could be of considerable importance to the abundance and distribution of wintering birds and should be emphasized in any environmental impact statement concerning tidal power development.

Island Development

Several State, Federal, and private agencies support programs that acquire or protect the nesting islands of coastal Maine. Eider breeding colonies on privately owned islands usually are least protected. The future of the eider in coastal Maine depends largely on how the islands are developed for use, and whether the protection of eiders is considered in planning.

Small Hydro-electric Dams

This type of installation is currently being considered as a possible alterantive or supplement to other types of power supply in Maine. The effect of their operations on waterfowl depends largely on the number, location, and seasonal water level requirements of the impounded areas insofar as it effects depth, aquatic plant growth, exposure of mud flats, and ice formation. Construction and operation of a small power dam on the Kennebago River in Stetsontown, Franklin County, created sizeable, high quality palustrine emergent wetland adjacent to the river channel (Kennebago Logans). Waterfowl abundance was high in the area for a number of years but in the last 15 years, heavy recreation (fishing and summer homes) resulted in a sharp decrease of waterfowl.

Overhead Power Transmission Lines

Although the edge effect or openness of transmission line corridors benefits some terrestrial species, waterfowl often are killed when flying into the lines. The frequency and magnitude of such losses are directly related to their proximity to large waterfowl concentrations. Although not documented, several observers reported frequent waterfowl collisions with powerlines at Merrymeeting Bay (region 2) where a complex of lines crosses the Bay and adjacent tributaries (e.g., Chops, Abagadasset Point, and Cathance River). If more power lines are needed in the future, careful consideration should be given to their location, including the desirability of underground installation.

Game Farm Mallard Releases

Thousands of game farm mallards have been released to the wild for many years in Maine. "Easter ducks" often are released on town mill ponds, and for several years the Bowdoinham Rod and Gun Club released 1000 to 3000 "environmentally conditioned" domesticated mallards in the vicinity of Merrymeeting Bay and other areas throughout the State. There is little evidence these releases increased waterfowl abundance or hunting, and the Maine Chapter of The Wildlife Society opposes further releases. It is speculated that releases contributed to increased hybridization between mallards and Maine's native black ducks. Recent evidence suggests the frequency of black duck and mallard hybridism is increasing (personal communication from R. E. Kirby, Migratory Bird and Habitat Research Laboratory, U.S. Fish and Wildlife Service, Laurel, MD.; May, 1977).

SOCIOECONOMIC IMPORTANCE

Waterfowl resources are often categorized into either "consumptive" or "non-consumptive" uses. "Consumptive" infers the killing of waterfowl (hunting) as opposed to "non-consumptive", such as bird watching, art forms, and photography.

Consumptive Uses

The magnitude and economic importance of the waterfowl of coastal Maine are best appraised by analyzing duck stamp sales and waterfowl surveys. (Duck stamps are required for all hunters over 16 years of age.) Duck stamp sales in Maine average near 18,000 annually. Another 2000 hunters under 16 years old also hunt, which brings the total to approximately 20,000. About 83% of these hunt ducks (17% are stamp collectors, etc.) and hunt an average of 5.5 days per season, killing an average of 4.5 birds. The total waterfowl person-days of hunting in Maine is about 100,000 annually. The average hunter kills about one bird per day.

From 1966 to 1975 more than 75% of the waterfowl harvest of Maine was in the coastal counties. According to a 1972 to 1976 survey there were about 27,000 Statewide duck hunters. The average annual number of each species of duck killed, and the totals for each county, are given in table 15-10. They averaged about 8 ducks a season. The 8343 hunters of geese averaged 0.6 geese per season. About 73% (19,667) of the duck hunters and 67% (5573) of the goose hunters hunted in Wildlife Management Units 6, 7, and 8.

Economic surveys of hunting and fishing show waterfowl hunters in Maine spend an average of $83 per year on their sport (National Analysts 1978). If the number of waterfowl hunters in coastal Maine approximates 34,000 (which is higher than other estimates) as suggested by National Analysts (1978), the sport generates about $2.75 million annually.

Non-consumptive Use

Non-consumptive waterfowl use in coastal Maine has not been determined, but judging from the number of bird clubs and the interest in them, non-consumptive use is a common practice. Both consumptive and non-consumptive users contribute to the management and preservation of waterfowl by purchasing hunting licenses and duck stamps, and supporting habitat acquisition and protection.

MANAGEMENT

The term "management" in this section includes research or fact finding programs needed to provide a sound basis for overall management. This includes both population management through regulation, and habitat management through protection, acquisition, and development.

The U.S. Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildife have the responsibility for managing (including regulation) waterfowl in Maine. Overall, hunting regulations of waterfowl are a function of USFWS. Within its regulatory framework, hunting regulations imposed by the MDIFW may be more restrictive but never less so. In addition to providing enforcement personnel, both agencies carry out individual and cooperative research and management programs. The Moosehorn, Petit Manan, and Rachel Carson National Wildlife Refuges are managed by the USFWS. The Maine Cooperative Wildlife Research Unit, Maine Field Station, Migratory Bird and Habitat Research Laboratory, Biological Servies Program, and Wildlife Services, are Fish and Wildlife Service supported activities. Within the MDIFW, regional wildlife biologists are responsible for managing waterfowl areas and carrying out survey and inventory tasks within their regions. The migratory bird research leader (Orono, ME.) and assistants are responsible for planning, designing, coordinating, and executing the overall MDIFW scientific/technical migratory bird program. The latter is described in a comprehensive long range "Wild Duck Management Plan" (Spencer 1975). This

Table 15-10. Average Annual Number of Pond and Diving Ducks Killed by Hunters in the Coastal Counties of Maine from 1966 to 1975.[a]

Pond ducks

County of harvest	Mallard	Mallard H.R.	Mallard X.B.	Black duck	Gadwall	A. wigeon	G.W. Teal	B.W. Teal	Muscovy	N. shoveler	Pintail	Wood duck	Total dabblers	Percentage of total
Cumberland	537	44	114	4030	-	9	529	165	-	-	114	405	5947	12
Hancock	252	3	43	3451	-	22	762	136	-	-	37	199	4905	10
Kennebec	241	4	20	1508	4	33	624	298	10	3	29	632	3406	7
Knox	84	19	3	616	-	-	133	11	-	-	-	110	976	2
Lincoln	352	6	38	2436	5	6	1049	305	-	-	16	240	4453	9
Penobscot	157	83	22	2392	-	26	885	424	-	-	41	1378	5408	11
Sagadahoc	789	51	132	7410	5	33	5163	2713	-	2	164	205	16,667	35
Waldo	84	-	13	1495	-	-	377	77	-	-	40	328	2414	5
Washington	100	5	8	2208	-	5	889	135	-	-	4	14	3368	7
Total dabblers	2596	215	393	25,546	14	134	10,411	4264	10	5	445	3511	47,544	100

Diving ducks

County of harvest	Canvasback	G. scaup	L. scaup	Ringneck	C. goldeneye	B. goldeneye	Bufflehead	Ruddy duck	Oldsquaw	C. eider	King eider	Black scoter	W.W. scoter	Surf scoter	H. merganser	R.B. merganser	C. merganser	Total divers	Percentage of total
Cumberland	-	26	9	118	199	-	360	11	139	1235	-	287	276	402	41	27	-	3130	14
Hancock	-	29	2	65	350	27	395	-	548	2096	10	165	1568	800	71	112	29	6267	29
Kennebec	4	28	32	506	204	11	39	-	-	-	-	-	22	-	78	20	15	959	4
Knox	-	-	-	-	5	5	338	-	-	667	-	18	6	74	-	5	-	1118	5
Lincoln	-	-	-	132	71	-	428	15	86	747	-	19	105	164	24	13	-	1804	8
Penobscot	-	34	33	307	597	16	83	5	20	13	-	6	38	42	90	10	13	1307	6
Sagadahoc	-	54	18	42	99	-	399	30	-	351	-	26	-	41	11	5	4	1080	5
Waldo	-	2	1 0	151	78	-	15	9	-	-	-	-	-	-	20	-	-	285	1
Washington	-	8	13	68	160	-	424	-	359	935	-	491	993	2257	9	16	5	5738	26
Total divers	4	181	117	1389	1763	59	2481	70	1152	6044	10	1012	3008	3780	344	208	66	21,688	100
Grand total																		69,232	

[a] Adapted from Carney et al. (1978).

plan sets long range goals for assuring the continued well being of the waterfowl resources while providing recreational and aesthetic values. It also sets out to maintain waterfowl populations that will assure an annual harvest of approximately 100,000 birds. The plan covers the period 1975 to 1979 and provides management guidelines based on an analysis of past waterfowl populations, assessment of present conditions, and an evaluation of probable future conditions and needs. In addition to management and research programs, MDIFW also has an active and ongoing habitat acquisition program which places considerable emphasis on waterfowl. As an example, the Department either owns or manages approximately 200 State owned coastal islands that support waterfowl and/or seabird nesting colonies (see atlas map 3).

DATA GAPS

Current deficiences or gaps in the knowledge of waterfowl biology or ecology weaken efforts to manage and protect coastal waterfowl resources. Description of the data gaps here should provide some guidelines for future research.

The black duck traditionally was the most numerous and sought after duck of the Atlantic Flyway. Current information (primarily winter inventory data) suggests a long term gradual decline in abundance, but the reason for this decline is unknown largely because methods of waterfowl population appraisal generally are inadequate. Black duck population research is currently emphasized by the USFWS, the Canadian Wildlife Service, the Atlantic Flyway Council, and the MDIFW. In Maine, as well as throughout the range of black ducks in the United States, improved winter inventories and habiat surveys are needed. Other studies that concern black ducks are the effects of various pesticides (e.g., spruce budworm sprays) and environmental contaminants (particularly heavy metals) on waterfowl and other living resources. The effect of such agents on food abundance or availability could be limiting. The impact of hunting on black duck populations also needs study.

The value of eelgrass as food for wintering black ducks, as well as for other wintering waterfowl, has yet to be determined. Little quantitative information is available regarding coastal ice formation in winter and mortality of winter populations.

The effect of the "red tide" organism on waterfowl is a managment concern. Red tide has been common in much of coastal Maine in recent years and, although no waterfowl mortality has been observed in Maine, black duck mortality caused by red tide organisms occurred on Massachusetts' north shore. Whether contaminated waterfowl (those that have fed on toxic burdened invertebrates) are safe for human consumption is uncertain.

Little is known of the factors affecting the abundance of the common goldeneye. No comprehensive, definitive study has been made of this species in North America and very little banding has been carried out. The goldeneye is an important component of the coastal Maine harvest but the location of its breeding grounds is unknown. Most Maine hatched and reared goldeneyes are usually harvested in northwest Maine, adjacent areas in Canada, and northern Vermont. Little is known of the population dynamics or status of the species.

The ecological role of mergansers among coastal waterfowl merits further investigation. Their significance as predators on salmonids has not been evaluated in Maine and their relationship as food for wintering bald eagles particularly needs study. They often are prey for eagles and may well be carrying heavy loads of pesticides and/or heavy metals accumulated from the consumption of contaminated fish. The estuarine systems of the Penobscot and Kennebec Rivers are areas of particular concern.

CASE STUDY: THE BLACK DUCK

This description of the biology and habits of the black duck, a species nesting in freshwater wetlands of coastal Maine, is representative of the type of information that should be developed for all major ducks of coastal Maine. This species was selected because its breeding and wintering ecology have been studied in Maine in considerable detail (Coulter and Miller 1968; Hartman 1963; Mendall 1949; and Reinecke 1977). This case study essentially describes the arrival of the breeding pairs at the nesting area and their life through the following spring. Excellent resumes of the life history of black ducks (and other Maine waterfowl) are contained in Bellrose (1976b) and Palmer (1976).

After the breakup of winter ice, black ducks migrate from wintering areas along the coast of Maine to northern breeding marshes in Maine and Canada. Although the migrants travel in flocks, most birds pair before reaching the breeding grounds. Although older adult females frequently return to marshes they formerly used in previous breeding attempts (Coulter and Miller 1968), yearling females are much less precise. Black ducks breed and nest mostly in freshwater marshes, shrub swamps, beaver flowages, woodland brooks, and streams. The monthly activities (phenophases) of male and female black ducks are shown in figure 15-12.

Spring arrival dates vary according to the latitude of the breeding site and weather conditions. In coastal Maine most birds arrive in late March through mid-April. Within a week to 10 days after arrival the female examines terrestrial nesting cover either from the water or afoot. Most nests are constructed during the second week of April through the first week in May (Coulter and Miller 1968). Soon after arrival at the breeding marsh, mated pairs isolate themselves from others of their species and establish a prenesting territory. At this time males become protective and aggressive. They attempt to drive away other black duck males or pairs. Daily breeding and nesting activities consist of feeding, resting, plumage maintenance, courtship, copulation, and exploration of the breeding marsh.

The development of the female ovary in preparation for egglaying begins about 7 days before the first egg is laid. At this time the female experiences a change in nutritional requirements (Krapu 1977). Nesting ducks feed extensively on aquatic invertebrates at this time (Swanson et al. 1977). Although a vegetable feeder during much of the year, from 60% to 70% of the female black duck diet consists of clams, snails, mayflies, caddisfly larvae, sowbugs, and other invertebrates (Reinecke 1977).

The nest site selected by the female normally provides overhead cover and has sufficent ground litter available for her to dig a shallow cup in the ground with her feet. Other characteristics of the nest site are highly variable. The nest may be located on a floating bog mat, in the woods, or in a blueberry field a thousand or more feet from the nearest water. In sedge-meadows, leatherleaf (Chamaedaphne calyculata), sweetgale (Myrica gale), and sedges (Carex spp.) are common nest site habitats. Upland nests studied by Coulter and Miller (1968) were found in nettles (Urtica dioica), raspberries (Rubus spp.), and American yew (Taxus canadensis). The variability of black duck nest sites may prevent nest predators from forming an efficient search image for locating nests (Reed 1974). Coulter and Miller (1968) reported that at least a third of the female black ducks under observation produced a second clutch of eggs when the first was destroyed. Some produced third clutches.

A black duck clutch in Maine averages about 10 eggs (Coulter and Miller 1968). They are generally laid at the rate of one per day. The weight of a clutch is 60% of the weight of the female bird, and the physiological stress of egg production is associated with a weight loss of about 100 g during nesting, including 50 g of fat (Reinecke 1977). The lipid energy reserves carried by the female are a significant input into the energy requirement of the bird during reproduction (Owen and Reinecke 1977).

During egg-laying, the female usually visits the nest in the morning and spends an increasing amount of time (2 to 10 hours) at the nest as the clutch nears completion (Caldwell and Cornwell 1975). The female is rarely at the nest at night until the clutch is complete. During egg-laying, the male rests and preens when the female is in the nest, and joins her for feeding, bathing, and preening when she is away from the nest.

As the female increases her time at the nest, the bond between the pair weakens. Soon after the female begins incubating the clutch, the male abandons her, becomes less aggressive, and joins other groups of feeding and resting males. The female assumes sole responsibility for hatching the eggs and rearing the young.

After abandoning the females, the males form flocks and move to larger marshes and estuaries to molt their wing feathers and begin a period of flightlessness. The flightless period lasts about 4 weeks in May and June. By early fall most adult males concentrate on intertidal flats along the coast.

During incubation the females remain on the nest except for one to four (average of 2.3) rest periods of from 1 to 3 hours (average of 80 minutes) per day (personal communication from J. K. Ringelman, School of Forest Resources, University of Maine, Orono, ME.; June, 1978). Incubation of the clutch requires 25 to 27 days. The egg-bound ducklings establish vocal contact with the female and open (pip) the eggshells during the final 2 days of incubation. The downy young remain in the nest until they are dry and the sheaths have been rubbed from their down feathers. When they are dry and the weather favorable, the female leads them to water. The average life span of females is probably less than 2 years; Anderson (1975) reported mallards averaged only 1.7 years. This suggest most females produce only 1 or 2 broods per lifetime.

The mortality rate of juvenile black ducks is high. Despite the 10 egg mean clutch size (Coulter and Miller 1968), Spencer (1967) reported in an 18-year study the average class III (6 weeks to fledging) brood size was only 5 for the 560 broods observed. The range was 4.3 to 6.0 young per class III brood (figure 15-12).

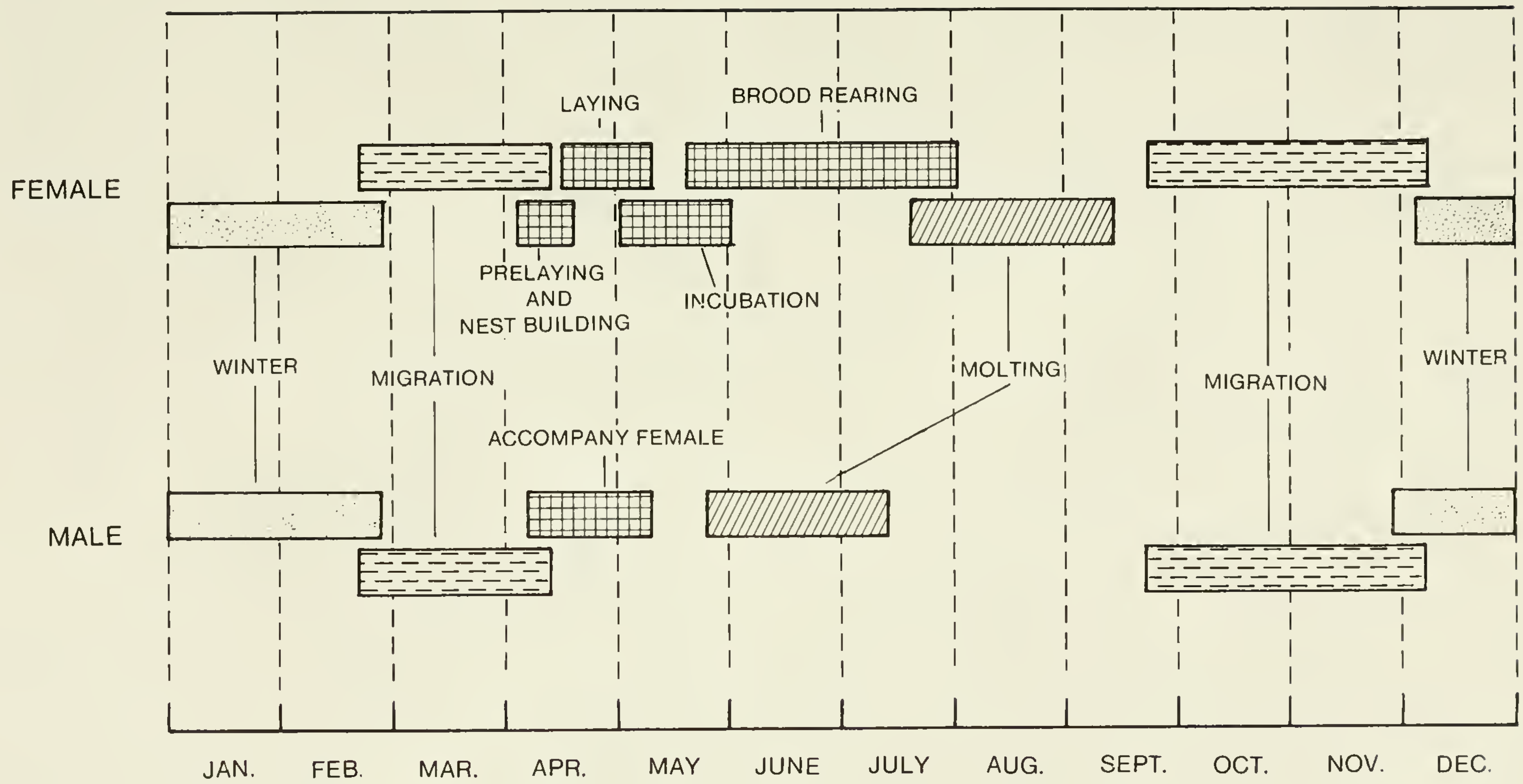

Figure 15-12. Phenophase Diagram of the Monthly Activities of the Male and Female Black Ducks in Maine.

The downy young feed at or above the water surface for 1 to 2 weeks; some of the food items described by Reinecke (1977) were chironomid (midge) pupae and adults, spiders, caddisflies, and mayflies. Aquatic invertebrates constitute about 90% (dry weight) of the diet of the young through the first 6 weeks of life. Snails, clams, mayflies, caddisflies, sowbugs, and fly (Diptera) larvae are an excellent source of highly digestible energy and protein for the young during rapid growth (2-10 weeks). By the age of 8 weeks the juveniles are consuming a diet higher in plant seeds and tubers and are making their first flights. In late summer the juveniles wander about, primarily on inland waterways (personal commuication from J. K. Ringelman, School of Forest Resources, University of Maine, Orono, ME.; June, 1978). The females that raised broods often remain at the breeding areas after the fledglings have gone. The adults undergo postnuptial molt of flight feathers at this time and may remain flightless until late September.

Black duck migration begins in August just after they regain their flight feathers. Many move down the major river systems toward the coast in fall. Some winter on the Maine coast and others winter south as far as North Carolina (Geis et al. 1971). Migration occurs principally during October and November and most reach their wintering grounds by early December.

Coastal Maine, which contains extensive black duck winter habitat, supported about 92% of Maine's wintering black duck population during January, 1979. The homing of black ducks to specific wintering areas or to breeding marshes in spring is equally strong (Spencer and Corr 1977). During winter the birds spend most of their time feeding and resting. Winter feeding is regulated somewhat by the tidal rhythms and weather conditions. Winter foods (Hartman 1963) include intertidal invertebrates such as the edible mussel (<u>Mytilus</u>), soft-shell clam (<u>Mya</u>), sandworms (<u>Nereis</u>), amphipods (<u>Gammarus</u>, <u>Orchestia</u>), and isopods (<u>Idothea</u>).

During severe weather, feeding birds remain in open water areas kept free of ice by the strong tidal currents. Winter is a period of high stress for black ducks on the Maine coast. Both adult and immature birds lose weight at this time. Reinecke (1977) estimated black ducks may starve in only 3 to 7 days if severe ice conditions prevent feeding.

Courtship activity and pair formation for the black duck begin in the fall and occur through the winter on warm sunny days. With increasing temperatues in February, courtship increases sharply and most birds are paired by the time spring migration brings the birds back to the nesting marshes.

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Chapter 16
Terrestrial Birds

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The birds discussed in this chapter are those that breed, migrate, or winter in terrestrial and vegetated palustrine habitats found along the Maine coast. Approximately 70% of the terrestrial birds found in Maine belong to the order Passeriformes, which includes warblers, vireos, flycatchers, thrushes, finches, and blackbirds. The remaining 30% include hawks (Falconiformes); grouse (Galliformes); woodcock, snipe, and killdeer (Charadriiformes); rails (Gruiformes); doves (Columbiformes); owls (Strigiformes); nighthawks and whipoorwills (Caprimulgiformes); swifts and hummingbirds (Apodiformes); and woodpeckers (Piciformes). This chapter does not discuss waterfowl (see chapter 15, "Waterfowl") or seabirds, shorebirds, and wading birds (see chapter 14, "Waterbirds").

Nearly 230 species of terrestrial birds have been observed in Maine. Fifty-seven of these only occur accidentally and are so rare they do not warrant further discussion (appendix table 5). Of the remaining 171 species, 95 are present only during the breeding season (late spring and summer), 51 are permanent residents, 15 are winter residents, and 10 are found only during the spring and fall migrations (tables 16-1 through 16-4).

Terrestrial birds are found in all types of terrestrial and vegetated palustrine habitats. They are generally abundant in Maine, as elsewhere, except during winter when terrestrial birds are scarce in Maine.

Terrestrial birds are important to people because of their recreational, sporting, and ecological values. People affect birds through habitat alteration, toxic chemicals, and accidental mortality.

This chapter summarizes the seasonal occurrence of terrestrial birds in Maine, their habitat preferences, relative abundance, important aspects of migration and reproduction, factors affecting abundance, effects of people on birds, and management recommendations and data gaps. Additional information on life history characteristics for individual species is given in appendix tables 1 to 4. A special case study on the status of bald eagles in Maine is also presented. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

DATA SOURCES

Information for this chapter was obtained from books and other published and unpublished souces. Breeding population trends were determined from data provided by the U.S. Fish and Wildlife Service's (USFWS) Cooperative Breeding Bird Survey (Robbins and Van Velzen 1974). Wintering population trends were obtained from Audubon Christmas Bird Counts published in American Birds (formerly Audubon Field Notes). Miscellaneous records for accidental visitants and rare breeders were accumulated from Maine Field Naturalist, American Birds, Maine Birds (Palmer 1949), and an Annotated Checklist of Maine Birds (Vickery 1978). Data on regional distribution were derived from Cruickshank (1950), Bond (1971), Knight (1908), Maine Field Naturalist, (1946-1969), and personal field experience. The Woodcock Management Plan (Corr et al. 1977a) and statistics from the Maine Department of Inland Fisheries and Wildlife (MDIFW) were examined for woodcock information. The distribution of each breeding bird species is currently (1979) being mapped by the Maine Breeding Bird Atlas program in cooperation with Bowdoin College.

SEASONAL OCCURRENCE

Most species (approximately 90%) of terrestrial birds found in Maine are migratory and are only present part of the year. Because of this, birds can be grouped according to their seasonal occurrence. The largest group consists of the 95 species that only are present during the breeding season (late spring and summer), and then migrate south of Maine for winter (table 16-1). The second largest group (51 species) consists of permanent residents; birds present in Maine throughout the year (table 16-2). Since the permanent residents also breed in Maine, the total number of terrestrial bird species breeding in Maine is approximately 145. It should be noted that many permanent resident species are also migratory, and while the species may be present year round, the same individuals may not be. Some individuals that breed in Maine migrate south for winter and are replaced by individuals that breed further north. A third group of birds is the winter residents (15 species; table 16-3). For the most part these are birds that breed further north (i.e., snowy owls and northern finches) and are present in Maine only during winter. The last group consists of 10 species that occur in Maine only during spring and/or fall migration (table 16-4). An important species in this group is the peregrine falcon, an endangered species. Small numbers of peregrines are observed each year along the coast of Maine as they migrate from breeding areas in northern Canada to wintering areas in the southern United States. Peregrines are usually seen along the marine shorline; over salt marshes, tidal mudflats, beaches, and on offshore islands. They are also observed from mountains along migration routes used by raptors. Peregrines occur in Maine from mid-March through mid-May during spring migration, and from mid-August through mid-November on the fall migration. They feed on large songbirds, shorebirds, and waterfowl that are abundant along the coast during migration.

Table 16-1. Relative Abundance and Habitat Preferences of Terrestrial Birds Found in Coastal Maine Only During the Breeding Season.[a]

Species	Relative abundance	Coastal shore-line, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Cooper's hawk	2								X	
Red-shouldered hawk	2				X			X	X	
Broad-winged hawk	3				X	X		X	X	
Marsh hawk	2			X	X					
Osprey	3	X	X	X						
Virginia rail	3			X						
Sora rail	3			X						
Common allnude	2			X						
American coot	2			X						
Killdeer	3				X					
American woodcock	3					X				
Common snipe	3			X	X					
Upland sandpiper	2				X					
Yellow-billed cuckoo	2					X		X		
Black-billed cuckoo	3					X			X	X
Long-eared owl	1								X	
Whip-poor-will	2					X		X	X	
Common nighthawk	3									X
Chimney swift	3						X	X	X	X
Ruby-throated hummingbird	3					X				X
Belted kingfisher	3		X							
Common flicker	3					X		X	X	X
Yellow-bellied sapsucker	3							X	X	X
Eastern kingbird	3					X				X
Great-crested flycatcher	3							X		X
Eastern phoebe	3					X				X
Yellow-bellied flycatcher	2			X			X			
Alder flycatcher	3					X				

a 1=rare; 2=uncommon; 3=common to abundant.

(continued)

Table 16-1 (continued)

Species	Relative abundance	Coastal shoreline, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Least flycatcher	3					X		X		
Eastern wood pewee	3							X		X
Olive-sided flycatcher	3						X			
Tree swallow	3		X		X					X
Bank swallow	3				X					
Rough-winged swallow	2		X		X					
Barn swallow	3									X
Cliff swallow	3									X
Purple martin	2									X
House wren	2					X				X
Winter wren	3						X			
Long-billed marsh wren	3			X						
Short-billed marsh wren	1			X	X					
Gray catbird	3					X				X
Brown thrasher	3					X				X
Wood thrush	3							X		
Hermit thrush	3						X		X	
Swaison's thrush	3						X		X	
Veery	3							X		
Eastern bluebird	2				X	X				X
Ruby-crowned kinglet	3						X		X	
Cedar waxwing	3					X				X
Loggerhead shrike	1					X				
Yellow-throated vireo	1							X		
Solitary vireo	3						X		X	
Red-eyed vireo	3							X	X	
Warbling vireo	3									X
Black-and-white warbler	3							X	X	X
Tennessee warbler	2			X			X			
Nashville warbler	3			X		X		X	X	X

(continued)

Table 16-1 (continued)

Species	Relative abundance	Coastal shore-line, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Parula warbler	3						X		X	
Yellow warbler	3				X					X
Cape May warbler	2						X			
Black-throated green warbler	3						X		X	
Black-throated blue warbler	3							X	X	
Blackburnian warbler	3						X		X	
Chestnut-sided warbler	3					X		X	X	X
Bay-breasted warbler	3						X			
Blackpoll warbler	2						X			
Pine warbler	3						X			
Magnolia warbler	3					X	X		X	
Prairie warbler	2					X				X
Palm warbler	2			X		X				
Ovenbird	3							X	X	
Northern water-thrush	3			X			X		X	
Mourning warbler	2					X		X	X	
Common yellow-throat	3			X		X				X
Wilson's warbler	2			X		X				
Canada warbler	3					X	X		X	
American redstart	3					X		X	X	X
Bobolink	3				X					
Eastern meadowlark	3				X	X				
Red-winged black-bird	3			X	X					X
Northern oriole	3									X
Rusty blackbird	3		X	X						
Common grackle	3			X						X

(continued)

Table 16-1 (concluded)

Species	Relative abundance	Coastal shoreline, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Scarlet tanager	3							X		
Rose-breasted grosbeak	3							X	X	
Indigo bunting	3					X		X		X
Rufous-sided towhee	3					X		X	X	X
Savannah sparrow	3				X					
Sharp-tailed sparrow	3			X						
Vesper sparrow	2				X					
Chipping sparrow	3					X				X
Field sparrow	2					X				
Lincoln's sparrow	2			X		X				
Swamp sparrow	3			X		X				

Table 16-2. Relative Abundance and Habitat Preferences of Terrestrial Birds Found in Coastal Maine Year Round.[a]

Species	Relative abundance	Coastal shoreline, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Goshawk	2							X	X	
Sharp-shined hawk	2								X	
Red-tailed hawk	2				X	X		X	X	
American kestrel	3				X	X				X
Spruce grouse	2						X			
Ruffed grouse	3					X		X	X	X
Ring-necked pheasant	2					X				X
Rock dove	3									X
Mourning dove	3				X	X				X
Great horned owl	2							X	X	
Barred owl	3						X		X	
Saw-whet owl	2						X		X	
Pileated woodpecker	2								X	
Hairy woodpecker	3							X	X	X
Downy woodpecker	3							X	X	X
Black-backed three-toed woodpecker	2						X		X	
Northern three-toed woodpecker	1						X			
Horned lark	2				X					
Blue jay	3					X			X	X
Gray jay	2						X			
Common raven	3						X		X	
Common crow	3								X	X
Black-capped chickadee	3					X	X	X	X	X
Boreal chickadee	2						X			

[a] 1=rare; 2=uncommon; 3=common to abundant

(continued)

Table 16-2 (concluded)

Species	Relative abundance	Coastal shoreline, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
White-breasted nuthatch	3							X	X	X
Red-breasted nuthatch	3						X		X	X
Brown creeper	3						X		X	
Mockingbird	2					X				X
American robin	3				X	X				X
Golden-crowned kinglet	3						X			
Starling	3				X	X				X
Yellow-rumped warbler	3						X		X	X
House sparrow	3									X
Brown-headed cowbird	3				X	X				X
Cardinal	2					X				X
Evening grosbeak	3						X			X
Purple finch	3						X			X
House finch	2									X
Pine siskin	3						X		X	X
American goldfinch	3					X			X	X
Red crossbill	2						X			
White-winged crossbill	2						X			
Dark-eyed junco	3						X			X
White-throated sparrow	3					X	X			X
Song sparrow	3				X					X
Bald eagle	2	X	X	X						

Table 16-3. Relative Abundance and Habitat Preferences of Terrestrial Birds Found in Coastal Maine Only During the Winter Months.[a]

Species	Relative abundance	Coastal shore-line, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Rough-legged hawk	2				X					
Snowy owl	2			X	X					
Great gray owl	1					X			X	
Short-eared owl	2			X	X					
Hawk owl	1					X				
Boreal owl	1						X			X
Tufted titmouse	1							X		X
Bohemian waxwing	2					X				X
Northern shrike	2					X				X
Pine grosbeak	3						X			X
Common redpoll	3					X			X	X
Hoary redpoll	1					X			X	X
Tree sparrow	3				X	X				X
Lapland longspur	1	X								
Snow bunting	3	X			X					

[a] 1=rare; 2=uncommon; 3=common to abundant.

Table 16-4. Relative Abundance and Habitat Preferences of Terrestrial Birds Found in Coastal Maine During Spring and/or Fall Migration.[a]

Species	Relative abundance	Coastal shoreline, islands, and headlands	Shores of rivers, lakes and streams	Vegetated wetlands	Open fields and wet meadows	Oldfields, successional habitat, and edges	Coniferous forests	Deciduous forests	Mixed forests	Suburban, urban, rural, and other developed areas
Golden eagle	1			X	X					
Gyrfalcon	1			X	X					
Peregrine falcon	2	X		X						
Merlin	2	X		X						
Red-headed woodpecker	1					X		X		
Western kingbird	2					X				X
Gray-cheeked thrush	2						X	X	X	
Water pipit	3				X					
White-crowned sparrow	3					X				X
Fox sparrow	3					X				X

[a] 1=rare; 2=uncommon; 3=common to abundant.

HABITAT PREFERENCE

An important characteristic of terrestrial birds is that each species has strong preferences for particular habitats, especially during the breeding season. While this is true of most wildlife, birds seem to be more selective than other vertebrates and their habitat preferences are better known. Factors important in habitat selection include the type of vegetation (grasses, herbaceous plants, shrubs, and trees), vegetation structure (density, height), plant species composition (deciduous, coniferous), presence of particular nesting sites or cavities and preferred nesting materials, song perches, and food abundance.

The habitat preferences of terrestrial birds are indicated in tables 16-1 through 16-4. For simplicity, nine classes of habitats are identified: (1) coastal shoreline, islands and outer headlands; (2) shores of lakes, ponds, streams, and rivers; (3) palustrine; (4) open fields and wet meadows; (5) old fields, edges, and other early successional habitats; (6) coniferous forests; (7) deciduous forests; (8) mixed forests; and (9) rural and developed land. Brief descriptions of these habitats, and the birds commonly occurring in each, follow.

Outer Islands and Headlands

Coastal islands and upland habitats along the shores of marine and estuarine waters are the primary nesting habitat for two very important terrestrial bird species; the bald eagle and the osprey. Both species nest in large trees near water, usually in areas with little human disturbance. Both species also nest inland along shores of lakes, ponds, and rivers, and in palustrine habitats, but the majority of their breeding populations are located along the coast.

The coast is also an important migration area for peregrine falcons and merlins. Many other species migrate along the coast but use habitats not unique to the coast. Snow buntings and lapland longspurs may winter along the coast as well.

Shores of Lakes, Rivers, Ponds, and Streams

Only five species of terrestrial birds are found primarily along streams, lakes, and ponds, all of which are breeding species: belted kingfisher, tree swallow, rough-winged swallow, bald eagle, and osprey. The belted kingfisher nests in holes dug into banks and feeds on small fishes. The two swallows nest in cavities and feed on flying insects over the water. Bald eagles and ospreys also nest in these habitats, although they are most abundant along the coast and outer islands.

Palustrine

Approximately 28 species of birds utilize wetland habitats along the coast; 22 are breeding residents, one is a permanent resident (bald eagle), one is a winter resident (short-eared owl), and four are migratory residents. Breeding birds typically found in wetlands include rails (Virginia and sora rails, common gallinule, and American coot), Wilson's snipe, marsh hawks, marsh wrens, red-winged blackbirds, common grackles, common yellowthroats, Wilson's warblers, swamp sparrows, and Lincoln's sparrows. Others that may be found in wooded swamps include several warblers (Tennessee, Nashville, and parula warblers, and northern water thrush), the yellow-bellied flycatcher, and the rusty blackbird. During migration and/or winter, palustrine habitats are important for several raptors, including peregrine falcon, snowy owl, short-eared owl, gyrfalcon, and merlin.

Open Fields and Wet Meadows

Open fields and wet meadows are used by approximately 32 species of birds. They are used as feeding areas by species such as hawks and swallows that nest in adjacent habitats,and as nesting and feeding areas for blackbirds (red-winged, meadowlark, bobolink) and sparrows (song, savannah, vesper, field, and sharp-tailed; figure 16-1). If suitable nesting cavities are available, American kestrels will nest and feed in these habitats. Many species of hawks, blackbirds, and sparrows feed in open fields and wet meadows during non-breeding seasons, also.

Old Fields, Edges, and Successional Habitats

Nearly 60 species of birds are found in successional or edge habitats, including 34 breeding residents, 14 permanent residents, 7 winter residents, and 4 migratory residents. Successional habitats form a continuum from relatively open, young seral stages, such as those found on recently abandoned farmland or clearcut forests, to older stages dominated by tall shrubs and low trees. Edge habitats occur where two structurally different habitats come into contact. Edges are found where forests are adjacent to fields or clearcuts, around clearings within forests, along the margins of ponds, lakes and streams, along highway and transmission line rights-of-way, and in rural and urban areas. Because of the range of vegetation types found in successional and edge habitats, it is difficult to generalize about the bird species found there. Often many different successional stages are found in the same general area and birds preferring each stage are found together. There are a few bird species considered true "edge" species (table 16-5). Edge species require both of the component habitats for successful nesting, using one habitat type for nesting or as song advertisement areas, and the other for feeding. Bird species utilizing edge habitats, and successional habitats in spruce-fir, pine, and deciduous forests are listed in figures 16-1 through 16-4 respectively.

Forests

Bird populations in Maine's forests are usually the richest of any terrestrial habitats in both density and species. One reason is that forests have a variety of vegetative types (herbs, shrubs, and trees), and bird species adapted to utilize the different "layers" of forest vegetation occur together. In addition, there is usually a range of successional stages within forest stands caused by cutting, wind throw, or natural mortality that allows bird species adapted to early successional stages to exist.

Forest birds can be grouped into those found in coniferous forests and those found in deciduous forests. Mixed coniferous-deciduous forests are inhabited by both groups of birds.

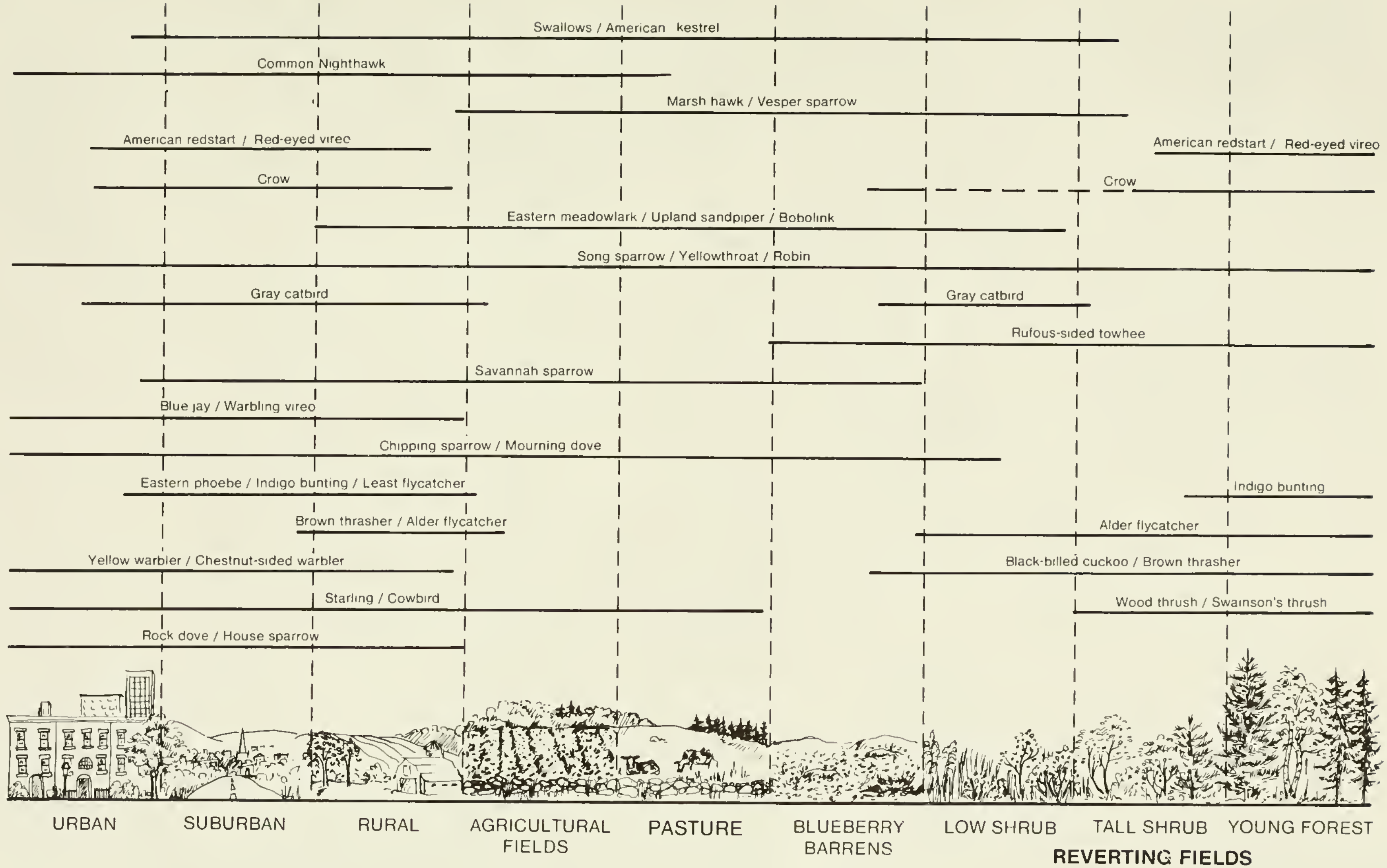

Figure 16-1. Urban, suburban, agricultural, successional, and edge habitats and their associated bird species. Horizontal lines indicate the range of habitats preferred.

Table 16-5. Common Edge Species of Birds in the Characterization Area

Mourning dove	Common yellowthroat
Black-billed cuckoo	Common grackle
Common flicker	Brown-headed cowbird
Eastern kingbird	Cardinal
Alder flycatcher	Indigo bunting
Blue jay	American goldfinch
Grey catbird	Rufous-sided towhee
Brown thrasher	Savannah sparrow
American robin	Vesper sparrow
Starling	Dark-eyed junco
Nashville warbler	Chipping sparrow
Yellow Warbler	Field sparrow
Magnolia warbler	White-throated sparrow
Chestnut-sided warbler	Song sparrow

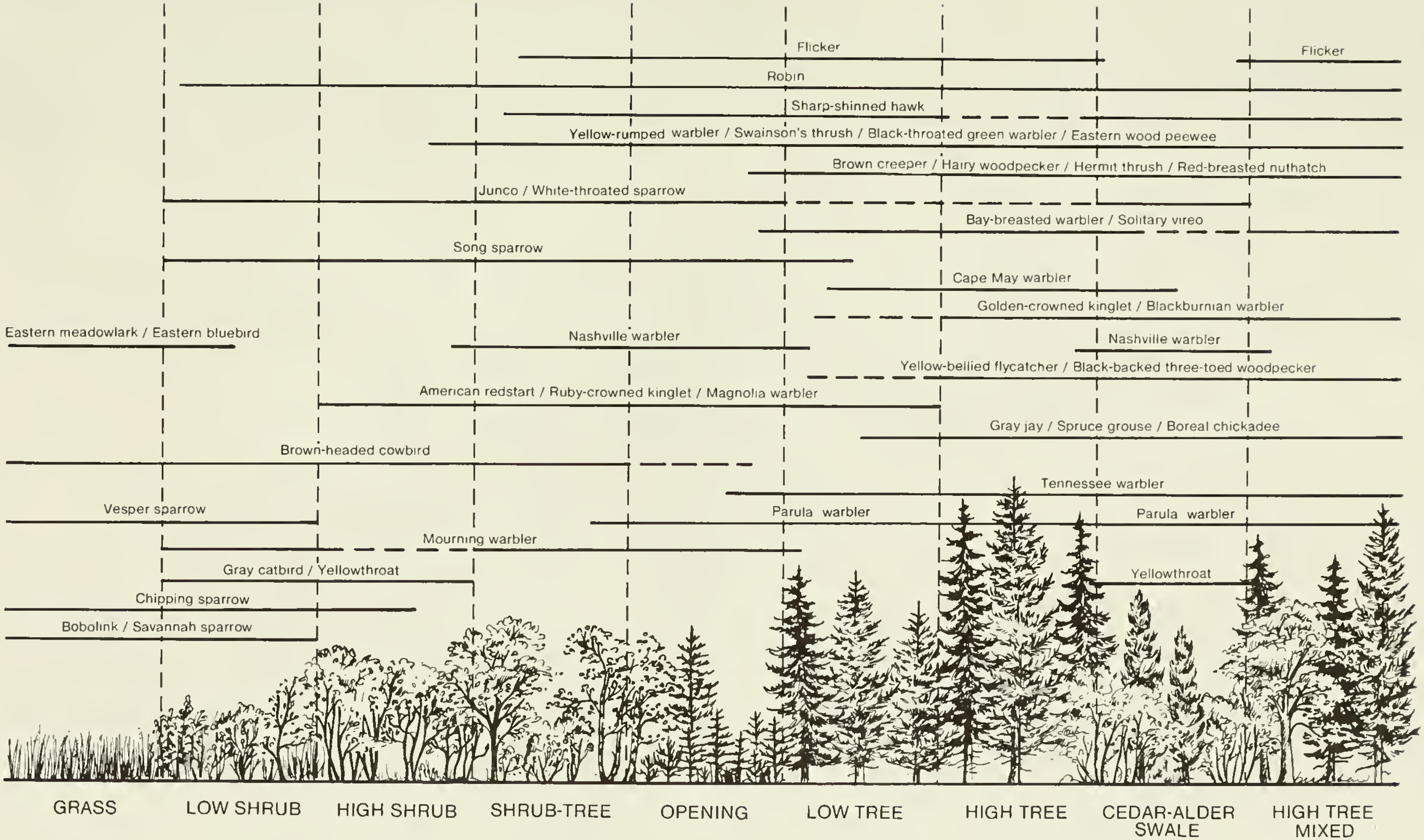

Figure 16-2. Generalized plant succession (from left to right) and associated bird species in a spruce-fir forest in Maine. Horizontal line indicate range of preferred habitat.

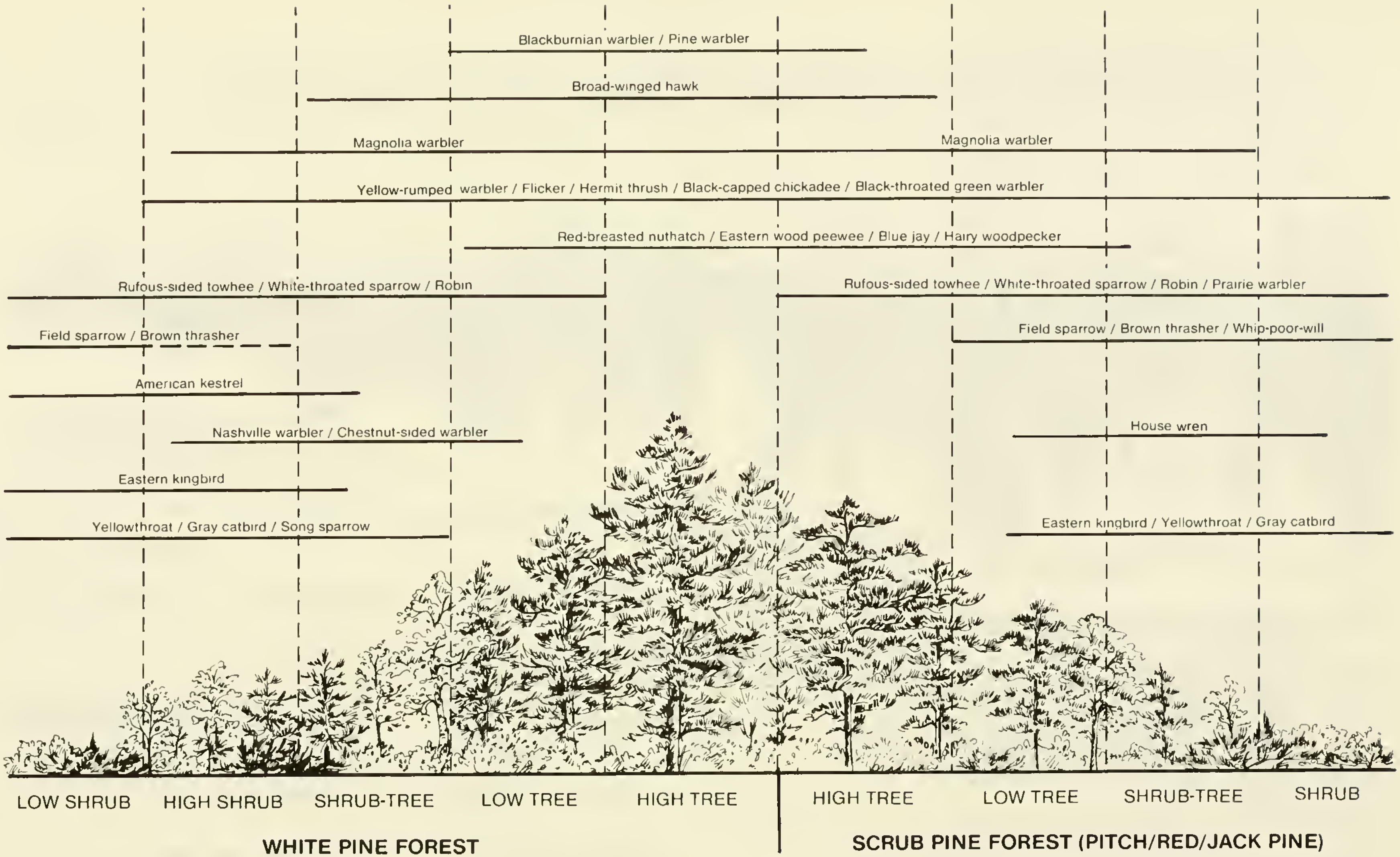

Figure 16-3. Generalized secondary plant succession and associated bird species in a white pine (left half) and scrub pine (right half) forest. Horizontal lines indicate range of preferred habitats.

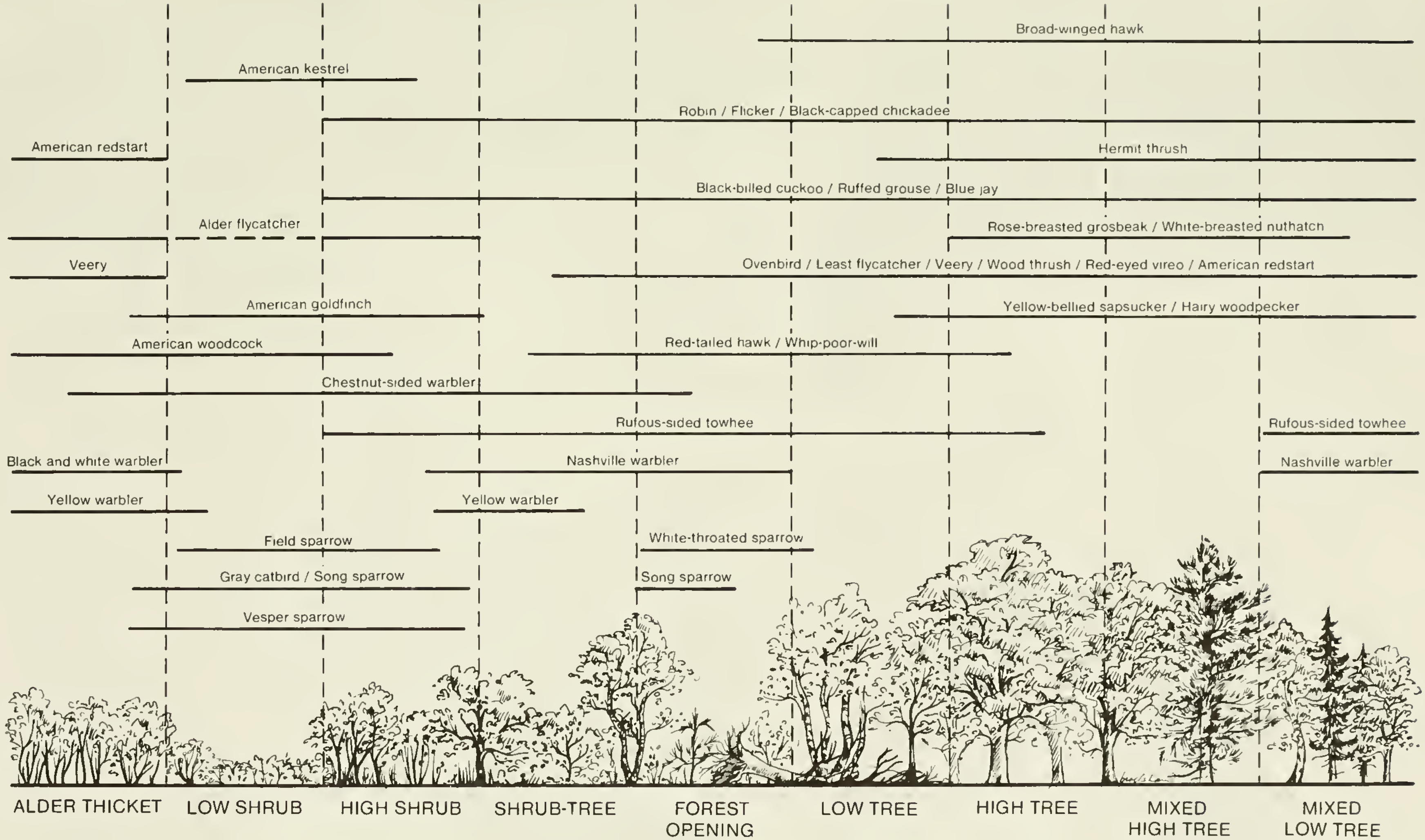

Figure 16-4. Generalized secondary plant succession (from left to right) and associated bird species in the deciduous forest and mixed deciduous/coniferous forest. Horizontal lines indicate the range of preferred habitats.

Coniferous forests. Two major types of coniferous forests are found along the Maine coast: spruce-fir and white pine-hemlock-hardwood (see chapter 9, "The Forest System"). A third type, scrub pine, is locally common in the characterization area. Fifty-nine species of terrestrial birds regularly occur in coniferous forests. Thirty-four are breeding residents, 14 are permanent residents, 7 are only present during winter, and 4 only during migration (tables 16-1 thorugh 16-4).

Spruce-fir forests are composed of balsam-fir (Abies balsamea), and red, white, and black spruce (Picea rubens, P. glauca, and P. mariana). The bird associations occupying these forests have been studied extensively in Maine, and habitat requirements of most species are fairly well known (Davis 1960; Morse 1968, 1971a, 1976, 1977; Rabenold 1978; Crawford and Titterington 1979; and Titterington et al. 1979).

Characteristic bird species found in mature spruce-fir forests are blackburnian, black-throated green, and yellow-rumped warblers, golden-crowned kinglets, and hermit and Swainson's thrushes. Cape May, Tennessee, and bay-breasted warblers are frequently found in spruce-fir stands infested with spruce budworm. The parula and magnolia warblers, slate-colored junco, and white-throated sparrow are found in young forests, and in disturbed or open stands with well-developed understories. The common bird species associated with all successional stages of spruce-fir forests are depicted in figure 16-2.

The other type of coniferous forest common along the Maine coast is dominated by white pine (Pinus strobus), eastern hemlock (Tsuga canadensis), and several hardwood species. The understory and shrub layers are generally more developed in pine-hemlock-hardwood stands than in spruce-fir. Characteristic bird species found in these forests include pine, black-throated green, yellow-rumped, Canada, and black-and-white warblers, common flickers, and white-throated sparrows (figure 16-3).

A third type of coniferous forest found along the coast is a scrub pine community. These stands are dominated by either jack, pitch, or red pine (Pinus banksiana, P. rigida, and P. rubra, respectively). These forests are characteristically low and open with a dense ericaceous shrub layer and, because of this, many species of birds assocaited with these habitats are early successional or edge species. Common birds include rufous-sided towhees, white-throated sparrows, Nashville warblers, common yellowthroats, and yellow-rumped warblers (figure 16-3).

Deciduous forests. Deciduous forests in coastal Maine are usually intermixed with coniferous forests. Large continuous areas of deciduous forest are uncommon along the immediate coast. Mature deciduous forests are multilayered (ground, shrub, low and high canopy trees), while successional forests, dominated by birches (Betula spp.) and aspens (Populus spp.), have only overstory and shrub layers. Approximately 35 species of terrestrial birds utilize deciduous forests. Twenty-five are breeding residents, 8 are permanent residents, 1 is a wintering species, and 1 is a migratory resident (tables 16-1 through 16-4). The most common birds found in deciduous forests are the red-eyed vireo, ovenbird, least flycatcher, American redstart, veery, wood thrush, ruffed grouse, and yellow-bellied sapsucker (figure 16-4). The black-throated blue warbler, scarlet tanager, rose-breasted grosbeak, and pileated woodpecker are found in mature hardwood stands dominated by sugar maple (Acer saccharum), American beech (Fagus grandifolia), and yellow birch (Betula allegheniensis); the northern hardwoods.

Mixed forests. Bird species associations in mixed forests are difficult to characterize because of the intermixing of spruce-fir, pine, and deciduous forest bird communities. Species composition and relative abundance vary in proportion to preferred vegetation types. Mixed stands often have a greater diversity of bird species because of the combination of species adapted to each type. Approximately 53 species are found in mixed forests: 29 breeding residents, 20 permanent residents, 3 winter residents, and 1 migratory resident (tables 16-1 through 16-4).

Rural and Developed Land

Over 70 species of birds are found in habitats described as rural, suburban, or urban. Many of these species are successional and edge species. Thirty-five are breeding residents, 27 are permanent residents, 8 are winter residents, and 3 are migratory residents. Highly urbanized areas are dominated by 3 introduced species: starling, house sparrow, and rock dove or pigeon. The density of urban birds is often as high as in forested habitats because of the abundance of these 3 species (Erskine 1977). Bird species commonly found in rural or suburban areas include song sparrows, northern orioles, warbling vireos, house wrens, chipping sparrows, mockingbirds, mourning doves, swallows, chimney swifts, crows, blue jays, robins, yellow and chestnut-sided warblers, American redstarts, red-eyed vireos, and gray catbirds, among others (figure 16-1).

ABUNDANCE OF TERRESTRIAL BIRDS

The abundance of terrestrial birds is affected by several factors, including abundance of preferred habitats, food supply, weather, and predation (see "Factors Affecting Distribution and Abundance" below). On a local scale bird populations have been determined on small areas (<100 acres; <40 ha) by spot-mapping, which estimates the number of breeding pairs on a unit of land (Robbins 1970). The effects of various land use practices on breeding bird populations can be assessed using this method.

On a regional scale long term trends in the relative abundance of birds are determined with index counts of breeding (Breeding Bird Survey) and wintering (Christmas Bird Counts) birds. While these index counts cannot be used to predict the bird populations on any particular area, they can point out significant increases or decreases in the abundance of bird species which can then be examined more closely. Additional surveys have been made to determine the abundance of bald eagles and ospreys in coastal Maine. Information on the bald eagle is contained in a special case study at the end of this chapter. The relative abundance of each species of terrestrial bird found along the Maine coast is given in tables 16-1 through 16-4.

Breeding Bird Survey

This nationwide survey samples bird populations along randomly selected driving routes, each 25 miles (45 km) long. Birds are counted during 3-minute stops every half mile along a route. By comparing only routes run in consecutive years by the same person(s) (to reduce observer bias) trends in species abundance can be determined. The survey is biased in favor of those bird species found along secondary roads so comparisons of abundance between species are not valid unless habitat availability along routes is determined.

There are 17 breeding bird survey routes in the characterization area. Based on general vegetation zones suggested by Kuchler (1964) and Peterson (1975), these routes can be grouped into southern New England (4 routes in region 1), northern hardwood (9 routes in regions 2 to 5), and spruce-hardwood (4 routes in region 16).

The abundance of birds along survey routes is represented as either overall abundance (birds per route) or frequency of occurrence (percent of the 50 stops on which a species occurs). The 20 most common species in each of the three zones are summarized in table 16-6. Regions 1 to 5 show similar trends in species abundance, but region 6 has some important differences. Hermit thrushes, red-eyed vireos, Nashville warblers, and solitary vireos are more common in region 6 than elsewhere, whereas wood thrushes, yellow warblers, song sparrows, red-winged blackbirds, grackles, catbirds, and robins are less abundant. These differences result from differences in habitat availability due to changes in land-use patterns. Some of these changes are described in chapter 9, "The Forest System" and chapter 10, "Agricultural and Developed Land."

Breeding bird surveys have also been used to detemine trends in the abundance of individual species (table 16-7). Significant long-term increases in wood thrushes and rufous-sided towhees have occurred in the characterization area, probably because of natural range expansion. Hermit thrushes have declined perhaps because of interspecific competition with wood thrushes (Morse 1971b).

The breeding bird survey documented severe reductions in songbird numbers after spraying Phosphamidon and Fenitrothion for control of spruce budworm in New Brunswick (Pearce et al. 1976). Reduced numbers of small insectivorous songbirds were documented following severe cold springs in New Brunswick (Erskine 1978). In Maine, declines of swallows following a cold spell in May, 1974, and the effect of the cold winter of 1976 on species such a winter wren, yellow-bellied sapsucker, hermit thrush, ruby-crowned kinglet, and eastern phoebe, that winter in the southeastern U.S., have also been demonstrated using results from the Breeding Bird Survey.

The osprey is a breeding resident which is relatively abundant in coastal Maine. It nests on coastal islands and on the mainland along the shores of marine and estuarine waters. Available information on the locations of nesting ospreys is included in atlas map 4. No complete inventories of the breeding osprey population in coastal Maine have been conducted, but a majority of the island nests have been located.

Table 16-6. Average Number of Birds (in order of abundance) Counted per Route for Each Forest Type in the Breeding Survey for the Region of Coastal Maine in 1977.

Total (17)[a]	$\overline{X}$ per route	Region 1 Southern New England[b] (4)	$\overline{X}$ per route	Regions 2-5 Northern Hardwood (9)	$\overline{X}$ per route	Region 6 Spruce/ Hardwood (4)	$\overline{X}$ per route
Starling	56	Starling	53	Starling	57	Red-eyed vireo	63
Robin	44	Robin	41	Robin	50	Starling	55
Red-eyed vireo	44	Herring gull	36	Red-eyed vireo	40	White-throated sparrow	49
Common yellowthroat	33	Common yellowthroat	35	Common yellowthroat	32	Ovenbird	42
Ovenbird	27	Red-eyed vireo	35	Song sparrow	31	Robin	34
White-throated sparrow	26	Red-winged blackbird	26	Wood thrush	28	Barn swallow	34
Song sparrow	23	Song sparrow	24	Tree swallow	27	Common yellowthroat	32
Barn swallow	23	Common crow	23	White-throated sparrow	26	Nashville warbler	32
Tree swallow	23	Tree swallow	21	Barn swallow	25	Hermit thrush	29
Wood thrush	22	Common grackle	20	Ovenbird	24	Tree swallow	17
Common crow	18	Ovenbird	19	Chestnut-sided warbler	22	Common crow	
Red-winged blackbird	17	Blue jay	17	Veery	21	Wood thrush	15
Chestnut-sided warbler	17	Black-capped chickadee	16	American redstart	20	Solitary vireo	15
Veery	16	Wood thrush	16	Gray catbird	18	American redstart	14
American redstart	15	American goldfinch	15	Red-winged blackbird	17	Cliff swallow	14
Herring gull	15	Bobolink	13	Common crow	17	Veery	13
Gray catbird	14	Gray catbird	13	Bank swallow	16	Cedar waxwing	12
Common grackle	14	Chestnut-sided warbler	11	Common grackle	15	Chipping sparrow	11
Bobolink	13	Chimney swift	10	Bobolink	13	Bobolink	11
American goldfinch	12	Barn swallow	9	Blue jay	13	Chestnut-sided warbler	11

[a]Number of routes sampled.
[b]BBS ecological units.

Table 16-7. Indices of Relative Abundance for Birds in Maine determined from the 1971-77 Breeding Bird Surveys, (the 1976 Index was set at 100)[a].

Species	Index of Relative Abundance						
	1971	1972	1973	1974	1975	1976	1977
American kestrel	51	432	259	136	167	100	110
Rock dove	158	63	34	23	55	100	108
Mourning dove	100	126	7[illegible]	116	113	100	107
Chimney swift	106	133	146	126	90	100	115
Common flicker	132	147	127	93	112	100	116
Yellow-bellied sapsucker	245	202	175	147	118	100	56
Hairy woodpecker	29	35	26	24	122	100	140
Downy woodpecker	33	75	71	71	150	100	260
Eastern kingbird	120	120	106	84	106	100	118
Eastern phoebe	64	71	68	74	70	100	75
Alder flycatcher	43	69	30	71	121	100	101
Least flycatcher	47	63	47	55	46	100	132
Eastern wood pewee	82	89	96	96	78	100	109
Tree swallow	96	109	124	92	99	100	114
Bank swallow	311	210	348	214	96	100	136
Barn swallow	113	115	103	89	91	100	120
Cliff swallow	125	241	183	78	139	100	165
Blue jay	137	145	176	139	104	100	115
Common crow	104	73	79	87	94	100	88
Black-capped chickadee	137	133	151	131	106	100	176
White-breasted nuthatch	184	102	327	187	350	100	550
Winter wren	46	92	108	168	80	100	62
Grey catbird	59	68	74	73	88	100	94
Brown thrasher	129	105	64	70	95	100	102
American robin	128	119	114	100	106	100	101
Wood thrush	92	103	96	85	116	100	120
Hermit thrush	122	116	122	123	112	100	56
Veery	109	100	104	119	111	100	112
Ruby-crowned kinglet	71	64	57	71	96	100	20
Golden-crowned kinglet	0	.25	.25	0	37	100	22
Cedar waxwing	112	116	66	72	100	100	111
Starling	126	142	107	97	114	100	109
Solitary vireo	111	74	74	114	80	100	75
Red-eyed vireo	104	98	77	88	107	100	222
Black-and-white warbler	26	38	41	60	86	100	108
Nashville warbler	14	45	51	67	99	100	110
Parula warbler	25	56	41	46	64	100	104
Yellow warbler	70	63	59	60	56	100	99
Black-throated green warbler	32	46	61	63	74	100	117
Chestnut-sided warbler	44	68	69	60	95	100	147
Ovenbird	75	90	92	112	97	100	92

[a]Index was calculated after Bailey (1967).

(Continued)

Table 16-7. (Concluded)

Species	Index of Relative Abundance						
	1971	1972	1973	1974	1975	1976	1977
Common yellowthroat	71	75	92	92	111	100	103
American redstart	86	81	84	99	77	100	116
Bobolink	54	43	36	66	76	100	77
Eastern meadowlark	49	98	61	45	72	100	131
Red-winged blackbird	110	109	96	99	99	100	116
Northern oriole	138	79	100	139	71	100	102
Common grackle	150	139	148	138	110	100	98
Brown-headed cowbird	118	129	139	76	75	100	89
Rose-breasted grosbeak	83	77	57	81	97	100	113
Purple finch	107	88	91	85	81	100	77
American goldfinch	106	120	87	69	95	100	94
Rufous-sided towhee	148	109	93	117	125	100	128
Savanna sparrow	87	110	89	113	125	100	148
Chipping sparrow	140	177	95	66	115	100	121
White-throated sparrow	119	146	144	141	155	100	105
Song sparrow	93	103	98	93	104	100	112

Christmas Bird Counts

Wintering population trends of terrestrial birds are more variable than breeding populations. Weather severity, seed crops, small mammal populations, snow cover, breeding success, and fall migration patterns contribute to this variability. Many seed-eating and raptorial species occur on a cyclical or irregular basis corresponding to availability of food supplies on their breeding grounds. Invasions of northern seed-eating finches are synchronous throughout the U.S. in years of seed failures in the arctic and sub-arctic (Bock 1976).

People influence the local abundance of wintering birds by planting fruit- and seed-bearing plants, and by providing bird feeders. About 16 species of semi-hardy bird species are able to winter in Maine because of food provided at bird feeders (table 16-8).

The Audubon Christmas Bird Counts assess the relative abundance of birds during late December. These counts are inherently variable in both count effort and observer expertise, however, much of this variability can be removed by standardizing the counts and only comparing counts conducted during consecutive years. Evidence from an independent census method suggests that results from Christmas Bird Counts reflect real population trends, but they overemphasize roadside and urban birds and underestimate dispersed woodland species.

Table 16-8. Bird Species That Require Artificial Feeding for Successful Overwintering in Coastal Maine.

Ring-necked pheasant (stocked)
Mourning dove
Rock dove
Mockingbird
American robin
Starling
House sparrow
Red-winged blackbird
Rusty blackbird
Common grackle
Brown-headed cowbird
Cardinal
House finch
Dark-eyed junco
White-throated sparrow
Song sparrow

Relative abundance of terrestrial birds wintering in Maine from 1969 to 1977 is presented in table 16-9. The index shows differences in relative abundance for each species compared to a base year (1976) which was given a value of 100. The northern finches (pine siskin, common redpoll, pine grosbeak, and purple finch) show the greatest variability in abundance. With the exception of the tree sparrow, the sparrows generally have synchronous increases and decreases, particularly the song sparrow and white-throated sparrow. The hairy and downy woodpeckers, crow, starling, and goldfinch show little variation from one year to the next. The golden-crowned kinglet, yellow-rumped warbler, cowbird, purple finch, and junco have been generally decreasing, whereas the sharp-shinned hawk, mourning dove, northern shrike, and pine grosbeak have been increasing.

ASPECTS OF MIGRATION

Migratory birds arrive on their breeding grounds in Maine during April and May and depart for their wintering areas in late July, August, or September. During the spring period many other birds pass through Maine enroute to breeding areas farther north.

Weather has a major effect on arrival and departure dates of migrants. Inclement weather, particularly cold weather in early spring, adversely affects insectivorous species by reducing food availability. For example, in the spring of 1974 many scarlet tanagers died from starvation during a cold spell in late May that affected northern New England and New Brunswick (Zumeta and Holmes 1978). In spring, birds follow warm fronts north, and in fall they move south with the prevailing winds of cold fronts.

Terrestrial birds migrate along the coast, along major inland waterways, and along prominent geological features such as mountain ridges (especially hawks which utilize deflected winds for soaring). In spring many insectivorous birds follow river valleys north feeding on emerging insects. In fall they return to Maine and concentrate along the coast, after which they either fly directly to wintering areas in the West Indies or move in a southerly direction along the coast. Raptors, particularly peregrine falcons, merlins, kestrels, sharp-shinned hawks, and cooper's hawks, follow the coastline. Their primary prey are other smaller migrant birds. Peak movements of sharp-shinned hawks correspond with large movements of flickers, a frequent prey item of these hawks. Marsh hawks in Maine are more common along the coast than inland. They prey on shorebirds, other small birds, and small mammals in estuarine emergent marshes and coastal barrens. Areas along the coast at which hawks are known to concentrate are Harpswell Neck (region 1), Baileys Island (region 1), the Camden Hills (region 4), Mt. Waldo (region 4), the hills bordering Somes Sound (region 5), and Cadillac Mountain (region 5). Coastal peninsulas in region 6 are also used by migrating hawks but quantitative data are lacking.

REPRODUCTION

Time of Nesting

The nesting period for most terrestrial bird species breeding in coastal Maine extends from May through July. Some species initiate nesting activities earlier (hawks, owls, and ravens) or later than this (goldfinches and cedar waxwings). Most migratory species begin nesting between mid-May and the first week of June. Individuals from the southwesternmost portions of the characterization area (regions 1 to 3) may begin nesting up to 10 days earlier than individuals of the same species nesting in the northeastern portion (region 6). Because the nesting season in Maine is relatively short compared to other areas of the U.S., most species raise only a single brood.

Nest Type and Location

Terrestrial birds nest in many locations either in open nests or cavity nests. Open nests are more exposed to predators and weather than cavity nests. They are placed in shallow depressions on open ground (nighthawks and killdeers), in dense vegetation on or near the ground (many warblers, blackbirds, thrushes, and marsh hawks), in shrubs (thrushes, brown thrashers, and catbirds), in tree canopies (many warblers, vireos, grosbeaks, tanagers, accipiters, and broad-winged hawks), in large open trees (hawks and ospreys), and in or on buildings (swallows and phoebes). Cavity nesters use a wide range of nest sites, including tree trunks (woodpeckers, owls, kestrels, great-crested flycatchers, nuthatches, chickadees, and bluebirds), sand, gravel, and peat banks (bank swallows and kingfishers), and buildings, bridges, and bird houses (purple martins, rough-winged swallows, and tree swallows).

Table 16-9. Index of Relative Abundance for Birds Counted During Annual Christmas Bird Counts in the Characterization Area from 1969 to 1977; Indexes based on 1976 Index of 100.

Species	YEARS								
	1969	1970	1971	1972	1973	1974	1975	1976	1977
Goshawk	321	57	302	94	132	20	173	100	82
Sharp-shinned hawk	21	184	164	123	27	11	52	100	70
Rough-legged hawk	0	32	36	40	11	83	40	100	21
Bald eagle	199	96	134	159	80	86	142	100	157
Ruffed grouse	569	155	636	900	160	397	269	100	566
Rock dove	0	0	0	0	6	57	111	100	57
Mourning dove	4	5	23	27	48	82	77	100	79
Pileated woodpecker	9	3	0	0	167	77	386	100	57
Hairy woodpecker	88	137	132	135	87	145	112	100	110
Downy woodpecker	117	127	136	150	93	206	109	100	94
Blue jay	65	95	82	123	84	45	69	100	68
Common raven	238	183	194	227	56	59	133	100	102
Common crow	159	174	141	145	91	73	91	100	74
Black-capped chickadee	98	74	102	137	105	135	139	100	120
Boreal chickadee	723	230	504	203	130	206	381	100	183
White-breasted nuthatch	172	215	115	187	152	267	115	100	140
Red-breasted nuthatch	183	93	139	512	50	119	123	100	51
Brown creeper	215	42	108	88	72	155	78	100	57
Robin	44	4	147	18	56	18	28	100	14
Golden-crowned kinglet	310	61	406	364	244	470	89	100	86
Northern shrike	21	52	31	55	25	78	106	100	181
Starling	171	164	206	200	176	180	161	100	198
House sparrow	217	83	67	149	68	79	94	100	51
Red-winged blackbird	117	23	144	109	79	122	53	100	56
Common grackle	34	11	52	20	41	77	80	100	57
Brown-headed cowbird	1084	99	516	244	527	162	151	100	108
Evening grosbeak	49	58	79	53	15	48	33	100	33
Purple finch	6	87	172	25	16	6	9	100	14
Pine grosbeak	0	0	1008	1003	8	76	562	100	779
Common redpoll	6271	22	4168	21	3	9	593	100	1988
Pine siskin	610	76	542	290	33	23	59	100	139
American goldfinch	5	18	40	61	27	39	34	100	30
Dark-eyed junco	539	234	257	321	133	105	101	100	31
Tree sparrow	65	155	120	86	51	78	84	100	62
White-throated sparrow	29	1	8	11	39	9	15	100	4
Fox sparrow	32	1	15	5	5	6	5	100	4
Song sparrow	40	9	26	36	32	24	26	100	7
Snow bunting	229	381	149	123	0	0	77	100	68

Nesting Cycle

The nesting cycle of most terrestrial species may be divided into six phases (Black 1976):

1. Prenesting
2. Nest building
3. Egg laying
4. Incubation (brooding)
5. Nestling
6. Fledgling

Prenesting is the period between arrival on the breeding grounds and the beginning of nest construction. Pair formation, pair bond maintenance, and nest site selection take place during prenesting.

Nest building may take up to a week for most passerines. Eggs are usually laid at a rate of one per day, with incubation beginning after the last egg is laid. High energy demands are placed on the female during the egg laying period.

Brooding (incubation) keeps eggs at their optimal temperature and, to a lesser extent, provides a suitable humidity. Incubation for most small passerines lasts 12 to 14 days. Hole nesters incubate about 2 days longer than other small passerines (Welty 1975).

The nestling stage lasts 12 to 13 days. Energy demands again increase for both male and female as they feed the nestlings. Disturbance of nests after the 7th or 8th day of the nestling stage often results in premature fledging and subsequent loss of all or part of the brood.

Fledglings are under parental care for the next 10 to 12 days. These figures are average figures for small (warbler size) passerines and vary for individual species. Generally larger birds take longer for each phase.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE

Natural factors affecting the distribution and abundance of terrestrial bird populations include habitat availability, competition, predation, disease, and weather. The abundance of suitable habitat is the most important factor affecting bird distribution. Unless disturbed, terrestrial habitats in coastal Maine eventually become forested (see chapter 9, "The Forest System"). Palustrine sites also fill with sediment and organic matter and become forests, but this is a much longer process than on upland sites (see chapter 8, "The Palustrine System"). Natural factors returning forests to early successional stages include wind storms and fire, but people are the most influential force affecting land use patterns in coastal Maine.

Competition for nest sites, food supply, roosting sites, and song perches limit the population size of some species. Territoriality is an intrinsic spacing mechanism for most species of terrestrial birds, and tends to reduce intraspecific competition for food and nesting sites. Competition between species is avoided by slight differences in habitat preference, food habits, feeding behavior, or preferred feeding heights.

In general, predation and disease do not seem to be important factors limiting bird populations in coastal Maine. Ground nesters are more subject to predation than species nesting above ground or in cavities. Common predators on birds in coastal Maine include hawks, crows, ravens, blue jays, red squirrels, chipmunks, raccoons, foxes, coyotes, weasels, and domestic pets.

Human Related Factors Affecting Abundance

Human activities in coastal Maine affecting the distribution and abundance of terrestrial birds include habitat alteration, use of pesticides and herbicides, accidental mortality caused by collisions with automobiles or buildings, and hunting. Although the extent to which these factors effect bird populations in coastal Maine is not known, the general ways birds are affected are summarized below.

Habitat alteration. Any activity that alters the composition and structure of a plant community also affects the relative abundance and species composition of the bird populations. Humans induce changes through logging (clearcutting or partial cutting), fire, herbicidal application, highway construction, transmission line construction, brush clearing, cull removal, and urban or suburban development.

Extensive studies on the effects of clearcut logging on bird populations were conducted recently in northern Maine (Burgason 1977; Titterington 1977; and Titterington et al. 1979). Total densities of breeding birds decreased by half immediately after clearcutting, but increased to precut levels within 7 years. Species composition also was affected, since species preferring forest habitats were replaced by edge species and species preferring early successional stages.

Clearing for highway and transmission line corridors effects bird populations in a manner similar to that of clearcutting. Densities of breeding birds in a highway right-of-way decreased from 7 birds/acre (17 birds/ha) to 3 birds/acre (8.5 birds/ha; Ferris 1977). The association of birds replacing forest inhabiting species was mostly edge species and ground feeding birds. Unlike succession following clearcutting, the right-of-way association persists indefinitely because natural vegetation succession is arrested by mowing, herbicides, and brush clearing. An indirect effect of highways on bird populations results from increases in cowbird and starling populations along highways. Cowbirds are brood parasites and reduce the nesting success of other birds nesting in the right-of-way and adjacent forest habitat. Starlings use natural cavities as nesting sites and successfully outcompete native bird species for the limited number of natural cavities.

Herbicides are used to control hardwood tree species in spruce-fir areas. This affects bird populations by altering habitat structure and species composition (Best 1972; Dwernychuk and Boag 1973; and Beaver 1976). The birds most affected include those utilizing immature deciduous forests (birch-aspen-red maple forest type) and early successional habitats (many edge species). Ruffed grouse are adversely affected as their preferred food sources include aspens, which are target species for herbicide treatments.

Small alterations of habitats cause subtle changes in bird populations. The clearing of brush or the removal of blowdown trees in forests may lower the densities of birds utilizing the ground and shrub layers. Removing dead and diseased trees may reduce the number of hole-nesting species (McClelland 1977). Removal of hedgerows from agricultural and developed areas eliminates nesting cover and song perches for many edge nesting species that feed in fields or in hedgerow habitats (sparrows, certain warblers, blackbirds, flycatchers, and American kestrels). Hedgerow removal in England, for example, has been a major factor in the decline of species utilizing shrub habitats (Murton and Westwood 1974). Sand and gravel removal in bank swallow colonies during the breeding season results in swallow mortality.

Habitat modifications can be beneficial to birds. Populations of edge species and species breeding and foraging in open habitats increase as blocks of forest are removed. Bird species benefiting from forest clearing include bobolinks, meadowlarks, savannah sparrows, horned larks, blackbirds, mourning doves, kestrels, and killdeer. Birds benefiting from herbicide treatments include species utilizing young and old conifers because plant succession is directed toward the rapid return of coniferous forests. Deciduous forest and mixed deciduous forest seral stages are eliminated. In contrast to ruffed grouse, spruce grouse benefit from this type of silvicultural treatment. Chimney swifts, barn swallows, cliff swallows, purple martins, phoebes, nighthawks, and rough-winged swallows benefit from nesting directly in or on buildings, bridges, or other structures. Bank swallow colonies and kingfisher burrows increased with the commercial excavation of gravel and sand deposits. Three introduced species, starling, rock dove (pigeon), and house sparrow, are so well adapted to developed environments they are considered pests in many areas because of their habit of nesting in or on human dwellings.

Chemical contaminants. The primary sources of environmental contaminants that affect terrestrial birds in the characterization area are the chemicals used in spraying programs for the control of forest and agricultural insect pests. Secondary sources include heavy metal contamination , terrestrial oil spills, and air pollution. These have minor regional effects but may be significant locally.

Prior to 1972, DDT and its derivatives (organochlorine compounds) were major causes for the decline of certain terrestrial birds that eat fish or other birds, especially osprey, eagles, and accipitrine hawks (Cooper's and sharp-shinned). These chemicals degrade slowly and concentrate in tissues of birds high on the food chain.

Since 1972 organophosphate and carbamate compounds have been used for the control of insect pests in Maine. These compounds break down rapidly and do not accumulate to toxic levels within food chains. Chemicals now used for the control of spruce budworm are Sevin, Dylox, and Orthene. Sevin is used most extensively on Maine's forest lands. Dylox is used primarily along the coast (near blueberry barrens) because of its low toxicity to bumblebees which pollinate blueberries, and Orthene is used near lakes, ponds, and rivers. Other chemicals used in Maine (currently registered by the Maine Department of Agriculture, Pesticide Control Board) include Fenitrothion, Phosphamidon, Mexacarbate, Guthion, Lannate, and Matacil (currently in experimental use only, but expected to be registered in 1980). Sevin, Dylox, Orthene, Lannate, and Matacil do not cause acute damage to birds but may affect their behavior and reproductive success (Moulding 1976). Acute damage to birds from the spraying of Phosphamidon and Fenitrothion insecticides for spruce budworm control was reported in New Brunswick (Pearce et al. 1976; and Erskine 1978). Declines in the population of small, high canopy feeding passerines in sprayed areas were reported in 1975.

The major agricultural spraying program in coastal Maine is for control of the blueberry maggot (see atlas map 2 for the distribution of blueberry barrens). Guthion has been used since 1969 for the control of this pest. Prior to that, DDT and sodium arsenate compounds were used. Guthion is considered more toxic than chemicals used on spruce budworm. Three bird species (marsh hawks, vesper sparrows, and upland sandpipers) currently considered declining on a regional basis by the National Audubon Society (Arbib 1979), nest or feed in blueberry barrens sprayed with Guthion. The vesper sparrow began declining in eastern Maine during the 1940s (Bond 1947). The relationship between the declining populations of these species, blueberry field management techniques, and Guthion needs evaluation.

In addition to direct toxicity, insect control programs deprive birds of food during the breeding season, a time when nearly all terrestrial birds in coniferous forests are insectivorous. Most of these feed in the canopy where food loss from insect control programs is greatest. Outer canopy feeders (middle and upper canopy species) are most affected, while bark drillers, bark gleaners, ground feeders, and shrub feeders are less affected.

Although the subject has not been studied extensively, evidence suggests changes in behavior and reproductive success may be related to changes in food supply. For example, a recent study evaluating the effects of Sevin on birds reported a steady decrease in canopy feeders for 8 weeks following spraying (Moulding 1976). The decrease was the result of birds moving into nearby unsprayed areas where food was more accessible. These trends are similar to those reported for the insecticides Dylox (Chambers 1972; and Caslick and Cutright 1973), Orthene, and Matacil (Pearce 1970; and Moulding 1976). In the above studies a 12% to 16% decline in numbers was reported 2 to 3 weeks following field applications of the pesticides. Moulding's study extended to 8 weeks after spraying, at which time a 45% decline in bird numbers was reported. He concluded, "...nesting failure with concurrent food stress might lead to a breakdown in further nesting behavior or a shift toward unsprayed habitats for renesting later in the season, with a resulting site loyalty shift expressed the following year." The nestlings of birds flying longer distances to gather food in unsprayed areas could have reduced growth rates or reduced fledging success.

Accidental mortality. An estimated 62 million birds die annually in the U. S. as a result of collisions with automobiles and human-made structures (Banks 1979). An estimated 29% of human-induced mortality results from road kills. The most common victims are song sparrows, robins, house sparrows, small owls, and pine grosbeaks. Birds also collide with lighthouses, radio towers, transmission lines, large plate-glass windows, airport ceilometers, and bridges.

Little quantitative data on collision fatalities are available for coastal Maine. Kills have been reported for lighthouses and airport ceilometers (Ferren 1959; Fobes 1956; Packard 1958; and Reitz 1954) but mortality at large towers has not been reported in the coastal zone. Plate glass windows on large buildings and houses result in the death of many migrating birds.

Transmission lines also kill or injure large numbers of birds (Willard 1978). The magnitude of this problem is difficult to assess because victims usually do not fall directly below the lines or supporting structures and are usually removed by scavengers. However, researchers working along transmission lines agree power lines kill large numbers of birds. A recent symposium was conducted to evaluate the effect of transmission lines on birds (Avery 1978), and an environmental impact statement on the effects of transmission lines on wildlife was recently prepared for an area in northern Maine (Center for Natural Areas 1978). Both are important sources of data on actual and potential impacts and offer valuable management suggestions. Efforts to place lines away from migration routes or areas where birds must pass on a regular basis, such as between breeding and feeding areas, would be valuable. The placement of transmission lines leading from coastal power-generating centers needs to be considered in selecting future power generating sites.

Hunting mortality. Four species of terrestrial birds are hunted for sport in coastal Maine: ruffed grouse, American woodcock, Wilson's snipe, and ring-necked pheasant (raised and released for hunting). Hunting can account for a substantial portion of the annual mortality of these species, but the harvest levels are regulated so as not to be detrimental to their populations. Most woodcock and snipe harvested are migrants from other areas, but early season hunting takes many local birds. Breeding populations of woodcock appear to be stable (Corr et al. 1977a). Population levels of grouse are variable as is their harvest.

Other factors. Terrestrial birds are sensitive to disturbance during the breeding season. Disturbances early in the breeding cycle may cause birds to abandon their nests, while disturbances later in the cycle may cause young birds to fledge prematurely or cause increased predation on young birds. Cutting hay before young birds have fledged (i.e., late June and early July) may result in the loss of many field nesting species (bobolink, meadowlark, savannah sparrow, killdeer, and upland sandpiper). Disturbances early in the nesting cycle usually have less effect than disturbances later in the season since renesting may be possible.

IMPORTANCE TO HUMANITY

Terrestrial birds contribute to the quality of life along the Maine coast. They are important for hunting, bird watching and other recreational activities, or as indicators of environmental contamination.

American woodcock, Wilson's snipe, ruffed grouse, and ring-necked pheasant are hunted for sport in the characterization area. Woodcock and grouse hunting in Maine is among the best in the northeast. Nearly 30,000 people hunt woodcock and 12,000 people hunt grouse each year in Maine (Maine Department of Inland Fisheries and Wildlife statistics). Hunting and hunting-related activities contribute to local economies through the purchase of guns, ammunition, food, lodging, hunting dogs, and other supplies.

Bird watching, bird feeding, and natural history studies are important recreational activities in Maine. An estimated 100,000 households maintain bird feeders and in 1972 almost 6 million pounds (2.7 million kg) of bird seed were purchased in Maine (Cross 1973). Participation on Christmas Bird Counts increased from 100 in 1969 to almost 400 in 1977. In addition, accessories used for bird watching, such as binoculars, cameras, and field guides, contribute to local economies.

Some species of terrestrial birds accumulate high concentrations of toxic materials, such as heavy metals or persistent pesticides, as they pass through the food chain. For this reason birds can act as indicators of environmental contamination, particularly where large amounts of chemicals are used. The most vulnerable of Maine's birds are ospreys, bald eagles, shrikes, and Cooper's and sharp-shinned hawks, because they prey on high-level consumers, including fish and other birds.

Birds may be pests on certain agricultural crops. Blueberry growers consider birds, especially gulls, robins, and blackbirds, a nuisance because they feed on blueberries (Ismail et al. 1974). The magnitude of this damage has increased in recent years. Growers in mid-coast regions (regions 3 to 5) believe the problem to be more serious than growers in eastern Maine (region 6; Ismail et al. 1974). Small fields with good cover nearby are more often affected than larger fields.

Grouse and many species of finches (primarily pine grosbeaks) feed on buds or flowers of commercially important trees during fall, winter, and spring. This reduces productivity and may cause adventitious buds which disfigure trees. Feeding activity by woodpeckers may damage trees, and woodpeckers serve as vectors for the chestnut blight and dutch elm disease (personal communication from Dr. Richard Campana, Department of Botany and Plant Pathology, University of Maine, Orono, ME.; June, 1972).

MANAGEMENT RECOMMENDATIONS

Migratory game birds (common snipe, American woodcock, Virginia and sora rails, crows, and American coots) are managed by the U.S. Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildlife. Non-migratory game birds (ruffed grouse and pheasant) are managed by the MDIFW. The State prepared long range management plans for woodcock, ruffed grouse, and pheasant (Corr et al. 1977a, b, and c). Nongame terrestrial birds are protected by State and Federal laws. With the exception of the bald eagle (see case study below) no active management of nongame birds is currently underway in Maine.

The best recommendation for managing terrestrial birds is the maintainence of adequate amounts of habitats used by birds. Urban, suburban, rural, edge, and successional habitats can be expected to increase in the future in coastal Maine at the expense of forests and palustrine habitats. More emphasis should be directed to preserving mature forests and palustrine habitats, as well as coastal shoreline areas (beaches and salt marshes), and coastal islands and headlands used by nesting eagles and ospreys. Developed habitats can be enhanced for birds by leaving areas of natural and diverse vegetation in parks and along water courses and highway corridors. Hedgerows and fencerows should be encouraged in agricultural areas. Forest management alternatives benefiting birds include leaving cull trees for cavity nesters, cutting in small patches, and maintaining a diversity of successional stages in close proximity to one another.

CASE STUDY: THE BALD EAGLE

Introduction

Bald eagles (Haliaeetus leucocephalus) have been treasured as our national symbol in the United States since 1782. In the ecological community they have an additional value as high level consumers and indicators of environmental quality. A recent decline in their populations and the designation of eagles as an endangered species resulted in widespread concern for their status. Bald eagles nesting in Maine represent more than 90% of the known eagle population breeding in the northeastern United States. Maine's eagles, especially those inhabiting the characterization area, are more closely allied to those of the Canadian Maritime provinces. Eagles breeding in coastal Maine and Nova Scotia are the major remaining segments of a previously larger, continuous maritime eagle population.

Bald eagles inhabit the characterization area throughout the year. The Maine coast supports more than 75% of the State's resident breeding and wintering eagle populations and is used by spring and fall migrants. Coastal Maine offers food chains capable of supporting eagles throughout the year, relatively isolated sites for nesting habitat, and ice-free waters that enhance eagle winter residence.

Status

Taxonomy. The American Ornithologists' Union (1957) recognizes two subspecies of bald eagles. Breeding eagles and most wintering eagles in Maine belong to the northern race (H. l. alaskansus Townsend). Southern bald eagles (H. l. leucocephalus Linnaeus) are irregular visitors to the State. Palmer (1949) cited a confirmed occurrence of the southern race in coastal Maine in 1890. These divisions are now considered arbitrary but have influenced recognition of bald eagles as an endangered species.

Historical distribution and abundance. No early appraisals of bald eagle distribution or abundance in Maine are available. References to eagles appear in the notes of James Rosier (1605), Captain John Smith (1614), and John Josselyn (1672; in Palmer 1949) during explorations of coastal Maine. The Abenaki Indians' word for eagle was "Sowangan". The name "Swan Island" in coastal Maine (region 2 and 5) is an adaptation of this word and implies eagles were present, not swans, as commonly assumed (Palmer 1949). Names such as Eagle Island, Eagle Hill (regions 1, 4, and 5), Eagle Bluff (region 4), Eagle Lake, and Eagle Point (region 5), reinforce the historical importance of the eagle.

Previous population estimates imply eagle abundance in Maine has been relatively low since the turn of the century. Knight (1908) suggested that the breeding population did not exceed 100 pairs at the close of the 19th century. Palmer (1949) considered 60 breeding pairs to be a liberal estimate in the late 1940s. Historical breeding sites in the characterization area documented prior to the initiation of State nesting surveys in 1962, are summarized in table 16-10.

Table 16-10. Historical (pre-1960) Breeding Sites of the Bald Eagle in the Characterization Area.

Region and associated water body	Years	References
Region 1		
Casco Bay	1860s	Rolfe 1908
	1900s	Hardy 1908
	1950s	Allen 1955
Region 2		
Kennebec River	1870s-1880s	Spinney 1926
	1900s	Bent 1937
Merrymeeting Bay	1890s	Anonymous 1898
	1930s-1940s	Anonymous 1949 and Townsend 1957
	1950s	Packard 1955
Region 3		
Damariscotta River	1860s	Baird et al. 1874
	1890s	Willard 1906
	1950s	Anonymous 1953
Muscongus Bay	1930s	Norton unpublished
Region 4		
Penobscot Bay	1890s	Knight 1908
	1950s	Hebard 1960
Jericho Bay	1900s	Bent 1937
Patten Bay	1940s	Anthony 1947
Penobscot River	1940s	MacDonald 1962
Region 5		
Blue Hill Bay	1920s-1930s	Tyson and Bond 1941
	1950s	Townsend 1957
Dyer Bay	1950s	Spencer 1980
Frenchman Bay	1920s-1930s	Tyson and Bond 1941
Mt. Desert Island	1920s-1930s	Tyson and Bond 1941
	1940s-1950s	Long 1951 and Townsend 1957
Union River	1890s	Knight 1908
Region 6		
Dennys Bay	1930s	Norton unpublished
Englishman Bay	1870s	Longfellow 1876
Machias River	1900s	Palmer 1914
Narraguagus Bay	1940s	Anonymous 1945

Local groups, ranging between 25 and 52 eagles, were noted historically in coastal Maine at a large fish kill in Casco Bay (region 1; Josselyn 1672), as well as at Damariscotta Lake (region 3; Bent 1937), Penobscot Bay (region 4), and the Narraguagus River (region 5) during migration. Wintering eagles in Maine formerly were characterized as common to occasionally numerous in some coastal regions (Palmer 1949).

Breeding population. Nesting inventories from 1962 to 1979 identified 76 bald eagle breeding sites in the characterization area. Their distribution and recent occupancy status are shown in figure 16-5. Fifty-two of these sites have been occupied at one time or another since 1975. Eighty-three percent of the State's breeding sites are in eastern Maine between the Penobscot River and St. Croix River drainages, primarily in regions 5 and 6 and the interior portion of Washington County. Breeding sites for bald eagles in coastal Maine are included in atlas map 4.

Surveys of bald eagles nesting in the characterization area since 1962 are summarized in table 16-11. These data provide the best estimates of the annual breeding population and production of young. The apparent population trends are not actual but are the product of variations in sampling methodology. The data suggest coastal Maine's breeding eagle population is increasing and the number of occupied breeding sites nearly tripled from 15 to 40 between 1967 and 1978. Such apparent growth is primarily an artifact of improved survey coverage. The largest apparent advancement occurred during intensive search efforts of a recent study (Todd 1979; and Todd and Owen 1979). A 43% increase in the number of occupied sites between 1976 and 1978 paralleled 23% and 36% increases in the respective numbers of breeding sites and intact nests monitored in the characterization area. Discovery rates of new sites suggest the present survey efficiency does not exceed 80% of the total population. The apparent decrease from 1978 to 1979 reflects a loss of breeding pairs and/or the effects of a delayed survey in 1979. The latter probably underestimated the population size because some unsuccessful breeding pairs abandon their nests early.

The known production of fledgling eaglets in coastal Maine increased more than ten-fold from a low of 2 in 1967 and 1972 to a high of 26 in 1979. The increase is less dramatic on a production rate basis but average recruitment since 1976 is significantly higher than it was in previous years. Both nesting success (the number of occupied sites where eaglets fledge) and fledgling brood size (the number of eaglets fledging from a successful nest) increased significantly.

The recruiting of eagles in coastal Maine between 1977 and 1979 was 0.63 fledglings for each occupied site and 0.73 fledglings for each apparent nesting attempt (excluding nonbreeding pairs), both of which remain below minimal numbers required for population stability. Eagles nesting on Cape Breton Island, Nova Scotia, Canada (the other major breeding area in the Northeast) averaged 1.35 fledglings for each apparent nesting attempt during 1978 to 1979 (Smith, unpublished). The productivity of relatively healthy eagle populations in Michigan (Postupalsky, unpublished), Minnesota (Mathisen 1979), and Kodiak Island, Alaska (Delaney, unpublished) during 1977 to 1979 ranged between 0.95 to 1.09 fledglings per occupied site and 0.97 to 1.22 fledglings per apparent nesting attempt. The decline in fledgling recruitment of Maine eagles indicates its population is declining.

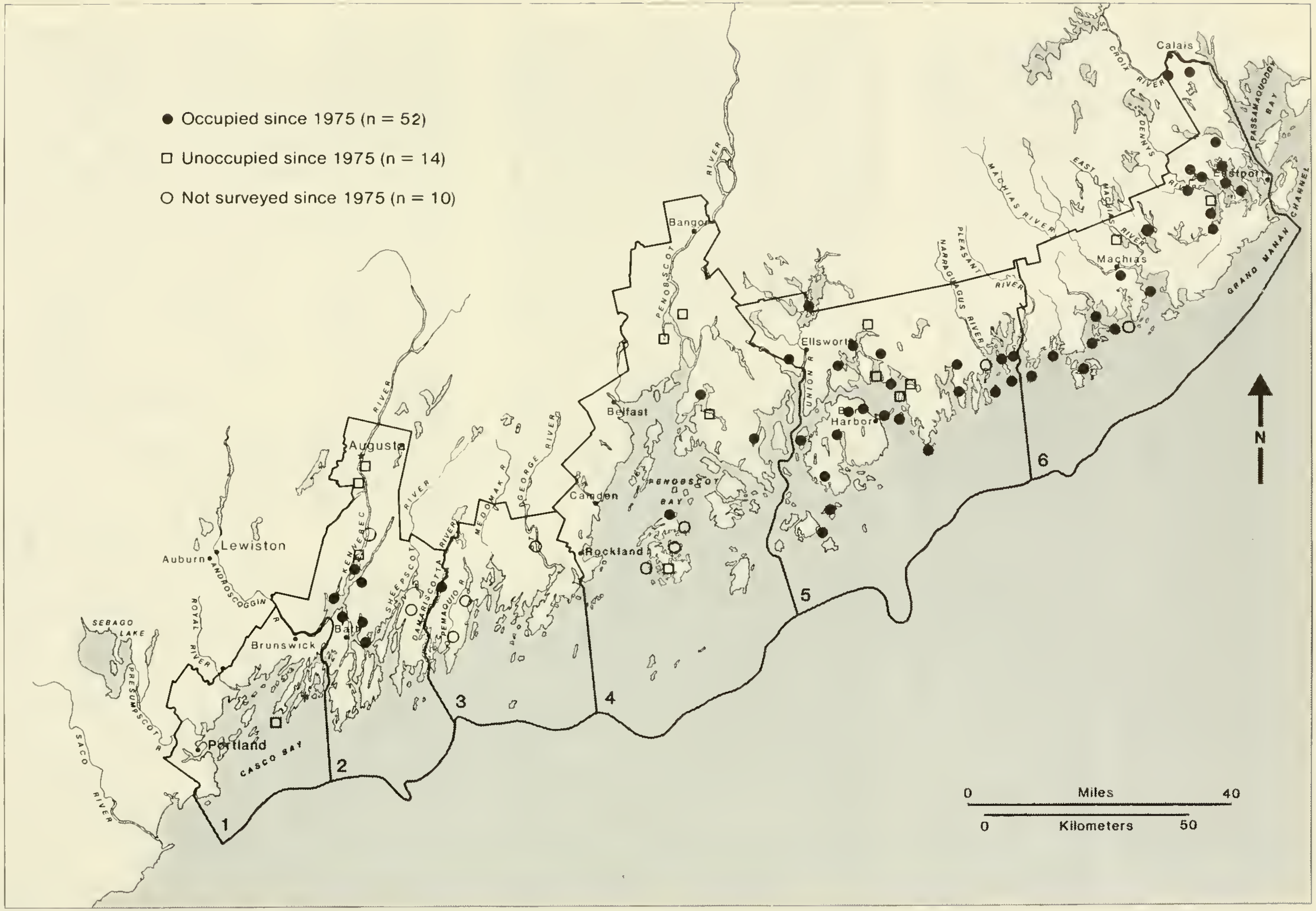

Figure 16-5. Distribution and occupany of bald eagle breeding sites in the characterization area in 1975 to 1979.

Table 16-11. Bald Eagle Nesting and Fledging Recruitment in the Characterization Area in 1962 to 1970 and 1972 to 1979.

Year	Number of Occupied sites[a]	Successful sites Number	Successful sites Percentage	Young fledged	Fledgings per Nest: Occupied (With and Without Broods)	Fledgings per Nest: Successful (Broods only)	Number of occupied nests with 0 to 3 fledgings: 0	1	2	3
1962	23	5	22	5	0.22	1.00	18	5	0	0
1963	22	7	32	9	0.41	1.29	15	5	2	0
1964	21	3	14	3	0.14	1.00	18	3	0	0
1965	26	3	12	3	0.12	1.00	23	3	0	0
1966	22	5	23	7	0.32	1.40	17	3	2	0
1967	15	1	7	2	0.13	2.00	14	0	1	0
1968	16	6	38	8	0.50	1.33	10	4	2	0
1969	19	7	37	10	0.53	1.43	12	4	3	0
1970	25	7	28	10	0.40	1.43	18	4	3	0
1972	20	2	10	2	0.10	1.00	18	2	0	0
1973	23	4	17	4	0.17	1.00	19	4	0	0
1974	28	8[b]	29[b]	8[b]	0.29[b]	1.00[b]	19	8[b]	0	0
1975	21	6[b]	29[b]	8[b]	0.38[b]	1.33[b]	14	4[b]	2	0
1976	28	10[c]	36[c]	16[c]	0.57[c]	1.60[c]	17	5	4[c]	1
1977	32	14	44	20	0.63	1.43	18	10	2	2
1978	40	12[d]	30[d]	21[d]	0.53[d]	1.75[d]	27	4	7	1[d]
1979	34	20[e]	59[e]	26[e]	0.76[e]	1.30[e]	13	14[e]	6[e]	0

[a]Data comparisons between the periods 1962 to 1967 and 1968 to 1979 are invalid because different criteria were used to identify occupied sites.
[b]Figures exclude one fledgling from successful egg transplant.
[c]Figures exclude two fledglings from successful egg transplants.
[d]Figures exlcude the known loss of one productive nest and three nestlings.
[e]Figures exclude two fledglings from successful eaglet transplants and known loss of one productive nest with one nestling.

Regional differences in number of breeding sites and eagle production are manifest among Maine's breeding eagles (table 16-12). Nearly two-thirds of the State's known breeding population and eagle production is in coastal Maine. More than 50% of these state totals are in regions 5 and 6. Highest nesting densities occur in the Frenchman Bay (region 5) and Cobscook Bay (region 6) vicinities, although recruitment is significantly greater in the latter where 1977 to 1979 means were 0.44 and 0.88 fledglings per occupied site, respectively. Recruitment rates in all regions are below population maintenance levels.

A striking decline in bald eagle breeding numbers in this century is apparent along the southwestern coast, especially in region 2. Fifteen occupied nests on the lower Kennebec River estuary dwindled to 3 by 1908 (Palmer 1949). Slightly upriver, the Merrymeeting Bay area was once characterized as having a "colony" of nesting eagles. These two areas were inhabited by only 1 and 2 breeding pairs respectively in 1979.

No occupied breeding sites have been found in region 1 since State nesting surveys began in 1962. A maximum of seven breeding pairs have been recorded in regions 2, 3, and 4 since 1977. Eagles nested successfully at only four of these sites. Early nesting surveys in Maine observed greater nesting activity in these western coastal and midcoastal areas. The contrast between past and present distribution patterns reveals a slight decline and/or shift of the State's resident breeding population.

Wintering population. Aerial inventories of wintering eagles in the characterization area totaled 98 eagles in 1977; 88 in 1978; and 88 in 1979. Midwinter populations in coastal Maine averaged 82% of the Statewide totals. Previous estimates of wintering eagle numbers in Maine were based on limited ground counts and are considerably lower. Long term indices of the State's winter eagle population are limited to results of Christmas bird counts sponsored by the National Audubon Society, and midwinter waterfowl and eagle inventories by Maine Department of Inland Fisheries and Wildlife. Extreme annual fluctuations in these data indicate the inappropriateness of Christmas counts as a measure of abundance.

The midwinter distribution of bald eagles in coastal Maine is summarized in table 16-13. Sixty-seven percent were found from the Penobscot River estuary eastward, almost evenly divided between regions 4, 5, and 6. Regions 1 and 3 receive light, variable use by wintering eagles.

Despite dispersion in the winter population, four areas of coastal Maine are significant wintering grounds. They are Cobscook Bay (region 6), Frenchman Bay (region 5), the Penobscot River estuary (region 4), and the Kennebec River estuary (region 2). Combined midwinter counts in these areas averaged 42% of 1977 to 1979 statewide populations.

Cobscook Bay, Frenchman Bay, and the Kennebec River estuary once supported comparable numbers of wintering and nesting adult eagles. The consistently high year-round population levels in the two former coastal areas reaffirm their crucial importance to Maine's bald eagles.

Table 16-12. Regional Variation in Bald Eagle Nesting and Fledging Recruitment in Maine between 1977 and 1979.

Area	Year	Number of breeding sites			Percentage nesting success	Number young fledged	Young fledged per nest	
		Surveyed	Occupied	Successful broods			Occupied	Successful broods
Coastal Maine	1977	60	32	14	44	20	0.63	1.43
	1978	65	40	12[a]	30[a]	21[a]	0.53[a]	1.75[a]
	1979	66	34	20[b]	59[b]	26[b,c]	0.76[b,c]	1.30[b,c]
Region 1	1977-79	1	0	0	-	0	-	-
Region 2	1977	9	2	0	0	0	0.00	-
	1978	9	3	0	0	0	0.00	-
	1979	9	3	1	33	1	0.33	1.00
Region 3	1977	1	1	1	100	1	1.00	1.00
	1978	1	1	1	100	2	2.00	2.00
	1979	1	1	1	100	2	2.00	2.00
Region 4	1977	6	2	1	50	1	1.00	1.00
	1978	7	3	2	67	4	1.33	2.00
	1979	7	2	2	100	2	1.00	1.00
Region 5	1977	25	15	7	47	11	0.73	1.57
	1978	26	17	4	24	6	0.35	1.50
	1979	26	14	7	50	8[c]	0.57[c]	1.14[c]
Region 6	1977	18	12	5	42	7	0.58	1.40
	1978	21	16	5[a]	31[a]	9[a]	0.56[a]	1.80[a]
	1979	22	14	9[b]	64[b]	13[b]	0.93[b]	1.44[b]
Interior Maine	1977	27	18	10	56	15	0.83	1.50
	1978	28	22	8	36	11	0.50	1.38
	1979	28	18	9	50	12[c]	0.67[c]	1.33[c]
Statewide total	1977	87	50	24	48	35	0.70	1.46
	1978	93	62	20[a]	32[a]	32[a]	0.52[a]	1.60[a]
	1979	94	52	29[b]	56[b]	38[b,c]	0.73[b,c]	1.31[b,c]

[a] Does not include the loss of one productive nest with three nestlings.
[b] Does not include the loss of one productive nest with one nestling.
[c] Does not include two fledglings from successful eaglet transplants.

Table 16-13. Number of Wintering Bald Eagles Counted and Percentage Mature in Maine During Mid-January 1977, 1978, and 1979.

Area	Year	Number of eagles			Percentage Mature/Inmature	
		Mature	Immature	Total	Mature	Immature
Coastal Maine	1977	81	17	98	83	17
	1978	72	16	88	82	18
	1979	75	13	88	85	15
Region 1	1977	3	1	4	75	25
	1978	2	1	3	67	33
	1979	1	0	1	100	0
Region 2	1977	6	4	10	60	40
	1978	6	4	10	60	40
	1979	5	4	9	56	44
Region 3	1977	8	1	9	89	11
	1978	2	0	2	100	0
	1979	4	1	5	80	20
Region 4	1977	23	3	26	88	12
	1978	15	3	18	83	17
	1979	16	2	18	89	11
Region 5	1977	19	5	24	79	21
	1978	28	4	32	87	13
	1979	26	4	30	87	13
Region 6	1977	22	3	25	88	12
	1978	19	4	23	83	17
	1979	23	2	25	92	8
Interior Maine	1977	16	2	18	89	11
	1978	17	4	21	81	19
	1979	18	3	21	86	14
Statewide total	1977	97	19	116	84	16
	1978	89	20	109	82	18
	1979	93	16	109	85	15

The Penobscot River estuary winter eagle population is derived strictly from seasonal immigration. Winter occupancy levels there vary more than those of other coastal regions, where resident eagles may remain throughout the year. The Kennebec River estuary is notable for high proportion of immature eagles among its wintering eagle populations. The 1977 to 1979 mean was 45%. This fact is significant in view of the nearly complete nesting failure of eagles nesting in the Kennebec River watershed. It confirms the probability of a seasonal influx of nonresident eagles into coastal regions where resident breeding populations may also winter.

The composition of coastal Maine's 1977 to 1979 midwinter eagle populations by age class averaged 83% adult and 17% immature eagles. Previous counts of eagles wintering in Maine also revealed a low percentage of immature birds, i.e., 11% in 1962 (Sprunt 1963), 21% in 1963 (Sprunt and Ligas 1964), and 14% in 1975 (Cammack 1975). Data computed over a period of years, 1961 to 1977 (Christmas Bird Counts) and 1963 to 1978 (Midwinter Waterfowl/Eagle Inventories), indicate only 21% immature eagles in Maine's wintering eagle population.

The age ratio is biased against immature eagles because their relatively inconspicuous plumage makes them less visible to surveyors. Poor reproductive success in Maine's breeding eagle population also contributes to low percentages of immature eagles. Age ratios of wintering eagles in the Pacific Northwest indicate a range of 35% to 52% immature individuals (Hancock 1964; Servheen 1975; and Stalmaster 1976). The latter figures probably reflect greater recruitment among eagles nesting in the Pacific Northwest.

Maine's midwinter eagle population is widely dispersed. The absence of large winter concentrations possibly reflects a lack of locally abundant foods which could result in a scarcity of immatures whose foraging skills are not well developed.

Migration. No data are available on migration of adult bald eagles from Maine. Only 16 immature eagles among those banded as nestlings in Maine have been relocated after fledging. Seven first-year, one second-year, and one third-year bird were found within 90 miles (145 km) of their natal nests in the State. Three others were seen during their first fall or winter in Maine and two wintered in Massachusetts. A two-year-old eaglet was relocated 220 miles (355 km) away in New Brunswick. The only documented case of dispersal out of the northeast was a juvenile observed in South Carolina, having traveled over 930 miles (1500 km) within 4 months of fledging in Maine.

Adult eagles were observed on 1977 to 1979 midwinter surveys at 20 coastal nest sites that had been occupied the previous breeding season. At least 45% of the breeding sites in the characterization area known to be inhabited during the 1976 to 1978 breeding seasons also were occupied in winter. Many pairs nesting on the coast remain on breeding territory throughout the year. However, winter ranges are flexible and change to meet the food supply. Fidelity to nests by wintering eagles supports the belief that much of the eagle population nesting in Maine also winters in the State.

Habitat

Characteristics of eagle habitat. Bald eagle habitat is closely associated with bodies of water, which provide the preferred diet of fish. Coastal marine and estuarine systems contain 82% of all the eagle breeding sites known in the characterization area. Lacustrine and riverine habitats support only 17% and 1%, respectively, of the breeding areas in coastal Maine. Most nests are located on offshore islands and nearby headlands adjacent to bays. The relative isolation of these sites offers ideal breeding habitat to eagles.

Bald eagles nest generally near large water bodies. The distance of 118 nest sites in Maine from open water averages only 149 yards (135 m). Eighty-one percent are within 275 yards (250 m). Mean distance from the shoreline varies significantly in different habitats from 44 yards (40 m) on coastal islands to 253 yards (230 m) on nearby headlands. This contrast between adjacent areas probably results from greater shoreline development and greater human activity on the mainland.

Nest locations near water provide both proximity to a food source and exposure of the site. Exposure allows maximum visibility from the nest, a clear flight path to and from the nest, and updrafts favorable for flight. The high proportion (88%) of supercanopy and dominant nest trees used by eagles in Maine also reflects exposure requirements. Seventy-three percent are old-growth white pines, which normally offer superior height and whorls of strong limbs to support nests.

Eagle populations in coastal Maine are probably largest during winter. All eagles observed in the characterization area during midwinter surveys were found in marine and estuarine habitats. Inland lakes, ponds, and rivers are used infrequently, since winter ice cover limits foraging opportunities. Wintering eagles also favor undeveloped shoreline habitats although they appear to be more tolerant of human activities than breeding eagles. Tall white pines near open water are favored winter perches. They provide a wide panorama, are accessible, and have stout horizontal branches for secure perching.

Food Habits

Bald eagles are capable but often inefficient predators and generally adopt an opportunistic strategy that includes scavenging carrion. They forage primarily in areas of open water. Land-based feeding attempts also are limited to open areas rather than forested habitats.

The diet of Maine eagles varies considerably in different habitats. More than 90% of eagle food remains observed at nest sites during the breeding season in freshwater habitats were fish, primarily bottom-dwelling species, such as brown bullhead, chain pickerel, and white sucker. Fish represent only 35% of the food debris in marine and estuarine systems. Bottom-dwelling species, such as tomcod and sculpins, often are eaten but eagles also eat alewives, blueback herring, and American eels.

Maine eagles increasingly depend on birds as a food source during winter. Avian remains constitute over 80% of eagle food debris in coastal Maine on a year-round basis. Twenty different species of waterfowl and seabirds are represented in the food remains and more than 50% are black ducks and gulls. Food-debris data are biased somewhat and underrate the incidence of fish because fish remains are digested or decompose rapidly.

Reproduction

Bald eagles are believed to mate for life. They exhibit high fidelity to their breeding sites. An individual pair may have several alternate nests but the same nest frequently is used in successive years. The distance between nests within a breeding area averages 0.9 miles (1.5 km) in Maine.

Some adult eagles are on territory by 25 February in coastal Maine. Prenesting activities include courtship flights and repairs or additions to the nest. The nest framework is constructed of limbs and branches of trees. Finer materials are used to line the nest interior. Over the years eagle nests become quite large. In Maine, nest size averages 5 feet (1.5 m) in diameter and 3 feet (1.0 m) in depth but ranges up to 10 feet (3m) and 17 feet (5m), respectively. Most eagle nests are built below the tops of trees but their bulk may eventually girdle and kill the treetop.

Considerable intraregional and interregional variation in the timing of reproduction is evident among eagles breeding in Maine. In coastal areas a clutch of 1 to 3 eggs is laid between early March and mid-April. Both adults brood the eggs but the female predominates throughout the 35-day incubation period. Incubation begins with the first egg laid, so hatching is staggered and siblings may differ in age and size. The time of hatching ranges from mid-April to mid-May. Eaglets remain in the nest for 10 to 13 weeks before making their first flights. Fledging dates occur potentially from mid-June to early August on the coast. Family groups may remain together into the fall before the young disperse.

Natural Factors of Abundance

Considerable habitat is available to bald eagles in coastal Maine, as evidenced by nearly 263,417 acres (106,647 ha) of inland wetlands (preliminary data of National Wetlands Inventory) and 4000 miles (6400 km) of irregular coastline. Natural limitations on eagle abundance are exceeded by limitations resulting from human activities. For example, habitat and food availability generally are not limiting, but modifications of the environment by people lowered habitat quality and contaminated the diet of eagles.

Inherent characteristics of the species, including recruitment, reproductive potential, and survivorship, limit the ability of bald eagles to recover from population declines. Field observations imply a lack of surplus nonbreeding adult eagles in Maine. A low reproductive potential, averaging only 1.3 fledglings/nesting attempt, is characteristic of eagles even in relatively healthy Alaskan populations (Chrest 1964; Hensel and Troyer 1964; and Robards and King 1967). High postfledging juvenile mortality is indicated by estimates of only 10% to 20% survival through 3 years of life (Sherrod et al. 1976; and Gerrard et al. 1978). Bald eagles do not attain maturity until the 4th or 5th year of life.

Human-caused Factors of Abundance

Human activities such as shooting, habitat alteration, and environmental pollution have affected bald eagle populations. Bald eagles historically have suffered from human persecution in Maine. Early settlers apparently used eagles for food on occasion (Palmer 1949). Moorehead (1922) found eagle bones among Indian shell heaps in Lamoine (region 5). The town of Vinalhaven (region 4) approved a 20 cent/head bounty on bald eagles in 1806 (Lyons et al. 1889) but this precedent was not adopted statewide. Eagle eggs were collected and offered for sale in the late 1800s. Spinney (1926) cited numerous instances in which pine trees supporting eagle nests were cut for timber.

Shooting has been the most common cause of mortality among Maine eagles in recent years. Both adult and immature eagles are shot, indicating the problem is not solely one of recognition. The frequency of shooting deaths among known mortalities of Maine eagles is near the 40% level observed nationwide. Shooting incidence declined nationally (Coon et al. 1970; and Prouty et al. 1977) but not in Maine. At least five eagles have been shot in coastal Maine since 1963. Other direct losses of eagles in Maine attributable to people are trapping, electrocution, and lead poisoning (via ingestion of waterfowl containing lead pellets). The impact of human-related mortality on an eagle population may exceed that of the normal decline in recruitment (Young 1968).

Environmental contaminants found in Maine bald eagles and in their eggs include 13 organochlorines and 5 heavy metals. Foremost are pesticides such as DDT and dieldrin, industrial wastes such as PCBs (polychlorinated biphenyls), and mercury. Residues of DDE and DDD (metabolic by-products of DDT), dieldrin, PCBs, and mercury occur in all eagle egg and carcass samples from Maine. Other contaminants appear at lower levels.

Contaminants at high levels are toxic to some animals but their persistence and cumulative effects at lower levels are not known for Maine eagles. They accumulate in eagles through contaminated foods and may be a threat to reproductive success. Reduced eggshell thickness and increased incidence of egg breakage are related to organochlorines, particularly DDE. Shell thickness of 34 eagle eggs collected in Maine between 1967 and 1979 averaged 0.52 mm, 15% below normal. No significant reduction in levels of DDE, PCBs, mercury or associated thinning has occurred in Maine eagle eggs since 1967. These contaminants probably have additive effects and their total impact is unknown. Embryo mortality observed at various stages in unhatched eggs of Maine eagles may be caused by DDE, PCBs and/or mercury.

The impact of organochlorines on bald eagle productivity in Maine becomes evident when the Maine eagle population is compared to those in other areas of the country. The amounts of residues of DDE, DDD, DDT, and dieldrin in Maine eagle eggs surpassed those of Florida and Wisconsin in 1968 (Krantz et al. 1970). Levels of contamination in Maine eagle eggs in 1969 were higher than those in Minnesota and Alaska (Wiemeyer et al. 1972). Recruitment also is lower among Maine eagles than in these four populations. Organochlorine residues similar to those in Maine eagle eggs were reported in northwestern Ontario, where productivity also was declining (Grier 1974). Detrimental levels of mercury in bald eagle eggs are relatively unique to Maine (Wiemeyer, unpublished).

Regional and habitat differences exist in levels of contamination in Maine eagle eggs (table 16-14). Eggs from western coastal regions have higher mean residues of DDE, DDD, DDT, dieldrin, and PCBs than those of eastern coastal regions. This evidence concurs with the low productivity of bald eagles in western Maine. Residues in eggs from coastal nests tend to be higher than those in eggs from inland sites which may reflect greater contamination in estuarine habitats and/or the higher trophic position of eagles in coastal Maine.

Limited sampling indicates Maine eagles receive these contaminants from food supplies within the State. Seven of 13 organochlorines present in Maine eagles and their eggs were found in fish and waterfowl samples collected throughout the State. Herring gull carcasses contained all 13 organochlorines. DDE, PCBs, and mercury residues are significantly higher in fish-eating species, such as herring gulls and mergansers, than in black ducks. This trophic relationship demonstrates the bald eagle's vulnerability to receiving concentrated doses of contaminants as a result of its terminal position in many food webs.

Four groups of eagle foods from Maine exhibited significant declines of DDE residues between 1966 and 1974. Trends in PCB exposure are uncertain but stable or increasing levels in fish and pooled black duck wings from Maine have been cited (White and Heath 1976; Wiemeyer et al. 1978). High mercury levels were detected in livers of mergansers from major eagle wintering areas on the Kennebec and Penobscot Rivers. Point sources of mercury pollution on the Penobscot River and PCBs on the Kennebec River have been cited (New England River Basins Commission 1977).

The impact of human activity on nesting bald eagles has not been documented in Maine. Nesting success in other eagle populations has been correlated inversely to permanent, visible signs of human proximity. Examples are buildings, roads, boat landings, and timber harvests (Juenemann 1973; and Grubb 1976). Two types of human disturbance have been observed to adversely affect eagle nesting in Maine, i.e., climbing to an active nest, and felling of a nest tree. A dirt road and power line were constructed to within 654 feet (20m) of a nest that was active in 1976 but which has since been abandoned.

Other less visible human activities also may affect eagles. Diminishing quantities of old-growth timber, especially white pine which is preferred by eagles for nesting, may present future problems. Disturbances to nesting eagles are most harmful during incubation (Mathisen 1968) and as eaglets approach fledgling age (Harper 1974; and Weekes 1975).

Increasing human activity and land development are encroaching upon favored eagle habitats in midcoastal and eastern coastal Maine (regions 4 to 6) and already have modified western coastal areas (regions 1 to 3) formerly occupied by a breeding population. Developmental projects potentially detrimental to the availablity or quality of bald eagle habitats or food supplies, merit careful evaluation, especially those affecting the population center and core of nesting in eastern coastal Maine.

Table 16-14. Contaminant Residue Concentrations (ppm wet weight, mean and range) in Unhatched Bald Eagles Eggs, by Location and Nesting Success in Maine between 1967 and 1979[a].

Category	Number of Eggs	Contaminants					
		p,p'-DDE	p,p'-DDD	p,p'-DDT	Dieldrin	PCBs	Mercury
Location							
Coastal Maine	18(15)[e]	21[b]	0.58	0.18	0.79	28	0.45
		12-42[c]	0.09-1.6	n.d.[d]-1.4	0.15-3.1	4.9-75	0.22-1.2
Western	7(4)[e]	23	0.93	0.27	1.5	44	0.57
		13-42	0.43-1.6	n.d.-1.4	0.70-3.1	18-75	0.48-0.66
Eastern	11	19	0.36	0.13	0.33	22	0.40
		12-35	0.09-0.84	n.d.-0.49	0.15-1.0	4.9-41	0.22-1.2
Interior Maine	7	16	0.25	0.22	0.31	20	0.59
		4.8-33	0.07-0.77	n.d.-1.2	0.09-1.0	5.4-39	0.26-1.2
Nesting success[f]							
Successful	9	13	0.31	0.11	0.25	18	0.48
		4.8-21	0.09-0.84	n.d.-0.49	0.09-0.31	4.9-41	0.26-1.2
Unsuccessful	16(13)[e]	22	0.59	0.24	0.89	30	0.50
		8.3-42	0.07-1.6	n.d.-1.4	0.09-3.1	11-75	0.22-1.2

[a] Wiemeyer, unpublished.
[b] Mean; calculations are based on clutch means.
[c] Range
[d] n.d.=not detected; lower detection limit=0.05 ppm.
[e] Parenthesized figure denotes different sample size for mercury and PCB analyses.
[f] Successful nests are grouped here as sites where eaglets have fledged at least once within 5 years of the egg-collection date. Unsuccessful nests are those where fledging did not occur within 5 years.

Socioeconomic Importance

The bald eagle has great aesthetic appeal to many people. The high level of interest in Maine eagles is evident from large-scale public participation in recent eagle count surveys. Citizens reported more than 5000 eagle sightings during a two-year period. Increasing demand is also reflected by the extent of press coverage of issues related to Maine eagles, public requests for slide shows and lecture programs, and a mailing list exceeding 1000 names for receipt of annual newsletters describing the status of Maine eagles. The recent designation of Maine's bald eagles as an endangered species should stimulate public interest further.

Bald eagles have been revered traditionally as the national symbol representing greatness, strength, and our natural resources. They also have an important biological role in removing weak, diseased, or otherwise less-fit individuals from prey populations. Furthermore, bald eagle populations serve as a sensitive indicator of environmental quality because of their susceptibility to chemical contaminants and other human alterations of natural systems.

Management

Protection. The Federal Bald Eagle Protection Act of 1940 made illegal the taking, possessing, selling, purchasing, bartering, transporting, exporting, importing, or shooting of any bald eagle, or parts thereof. In 1972 Congress established maximum penalties for shooting bald eagles as a $5000 fine and/or 1-year imprisonment. Convicted second offenders were penalized up to $10,000 and/or 2 years in prison. A further stipulation offered one-half of the fine to the person providing information leading to a conviction.

The southern bald eagle was listed officially as an endangered species in the Federal Register on 11 March 1967. The endangered status was extended to northern bald eagles in all but five of the 48 contiguous states on 14 February 1978. The latter designation included Maine, but excluded Michigan, Minnesota, Wisconsin, Oregon, and Washington, where eagles are listed as threatened.

The Endangered Species Act of 1973 thus provides further protection to Maine's bald eagles. Section 7 of the Act states:

> The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal departments and agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act and by taking such action necessary to insure that actions

> authorized, funded, or carried out by them do not jeopardize the continued existence of such endangered species and threatened species or result in the destruction or modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with the affected States, to be critical."

Critical habitat for bald eagles has not been officially identified, but efforts are underway nationwide to establish criteria for this designation. Regional Bald Eagle Recovery Teams were formed in 1978 to identify critical habitat and coordinate other aspects of bald eagle research and management. A recent study of bald eagles in Maine, co-sponsored by the U.S. Fish and Wildlife Service, the Maine Department of Inland Fisheries and Wildlife, and the University of Maine at Orono Wildlife Department (Todd 1979; and Todd and Owen 1979) provided a basis for these evaluations within the State.

Measures to protect Maine bald eagles were initiated prior to their designation as an endangered species since 1973. The U.S. Fish and Wildlife Service (FWS) coordinated a cooperative landowner agreement program to preserve eagle nest sites in the State (Gramlich 1975). FWS also conducted experimental transplants to bolster the depressed productivity of Maine eagles (U.S. Department of the Interior 1974, 1975, 1976, and 1979). A total of 18 eggs and nestlings from captive breeding or wild populations in Minnesota and Wisconsin were substituted for eggs of traditionally unsuccessful breeding pairs in Maine. Seven fledglings resulted. Four of the removed eggs hatched and were reintroduced via fostering. Improved techniques should permit greater success rates in the future.

Corr (1976) prepared a bald eagle management plan for the Maine Department of Inland Fisheries and Wildlife. He described basic population status, habitat availability, management concepts, and research needs. The latter were incorporated as basic research objectives of an intensive study conducted from 1976 to 1978 (Todd 1979; and Todd and Owen 1979). Investigations focused on the ecology of Maine's breeding eagles (nesting habitat, breeding chronology, population size, productivity, and factors affecting the population), wintering eagles (population size, distribution and location of major wintering areas), and eagle food habits (diet composition and contamination of food supplies). The results of this research provided a basis for updating Maine's bald eagle management program (Todd, in preparation). Management objectives reflect minimum levels of recruitment essential for population stability and future growth to achieve an eventual goal of declassifying Maine eagles as endangered. Proposed programs are grouped into inventory, research, management, and education functions (figure 16-6).

Guidelines for management of all known breeding sites in Maine are being developed on an individual basis, a policy initiated in national forests (Mathisen et al. 1977). Each plan summarizes all data available on physical habitat, nesting history, and research information at each site. Inquiries concerning possible site-specific impacts near important eagle habitats (see atlas map 4) should be directed to either (1) the appropriate regional biologist at the Maine Department of Inland Fisheries and Wildlife, (2) Wildlife Division Office, Maine Department of Inland Fisheries and Wildlife, Augusta, Maine, or (3) U.S. Fish and Wildlife Service, Augusta, Maine.

Research Needs

Important data gaps on Maine eagles are reflected by the proposed research objectives in the State's eagle management plan. This research is dependent on continued inventories of breeding and wintering eagles and their habitats. These programs facilitate more effective management and are compatible with guidelines being developed by bald eagle recovery teams.

The characteristics of suitable nesting and wintering habitat must be documented to permit critical habitat designations. Basic research is needed on winter habitat requirements in Maine (e.g., winter diet, tolerance to human activities, and the existence of nocturnal roosts). Studies of poorly understood aspects of eagle habitat use (e.g., feeding areas, home range, behavior, and tolerance to human proximity) are warranted in threatened habitats. Other life history data (longevity, recruitment, age at first breeding, juvenile dispersal, and age-specific survivorship) can be evaluated only on a long-term basis via banding. Evaluations of causes of mortality and contaminant levels in Maine eagles will be made as carcasses and unhatched eggs are found. Contaminants in food supplies and contributing sources need to be investigated periodically.

GOAL: Restore a self-sustaining bald eagle population to suitable habitat throughout Maine.

- INVENTORY
  - Nesting Survey — Annually monitor the size and productivity of Maine's breeding population.
  - Nesting Habitat Inventory — Identify and characterize all known current breeding sites, historical breeding areas and suitable, potential nesting habitat of bald eagles in Maine.
  - Winter Survey — Periodically monitor distribution, size and age composition of bald eagles wintering in Maine.
- RESEARCH
  - Life History Study — Conduct life history studies in bald eagle habitats threatened by development or other major alterations.
  - Contaminants Monitoring — Monitor organochlorine and heavy metal contaminants in Maine bald eagles and their foods.
  - Habitat Suitability Assessment — Identify the criteria for suitability of bald eagle breeding and wintering habitat in Maine.
  - Dispersal and Survival Studies — Obtain further data on dispersal and survivorship via banding of Maine bald eagles, especially juveniles.
  - Causes of Mortality — Continue investigations into causes of mortality in Maine bald eagles.
- MANAGEMENT
  - Habitat Management — Promote conservation of bald eagle nesting and wintering areas and enhancement of potential habitats in Maine.
  - Population Management — Enhance the viability of the bald eagle population breeding in Maine.
  - Management Strategy — Periodically update strategies for bald eagle management for the Maine Department of Inland Fisheries and Wildlife.
- EDUCATION
  - Information and Education — Maintain public awareness and interest in the status and management of Maine bald eagles.

Figure 16-6. Proposed bald eagle management programs of the Maine Department of Inland Fisheries and Wildlife.

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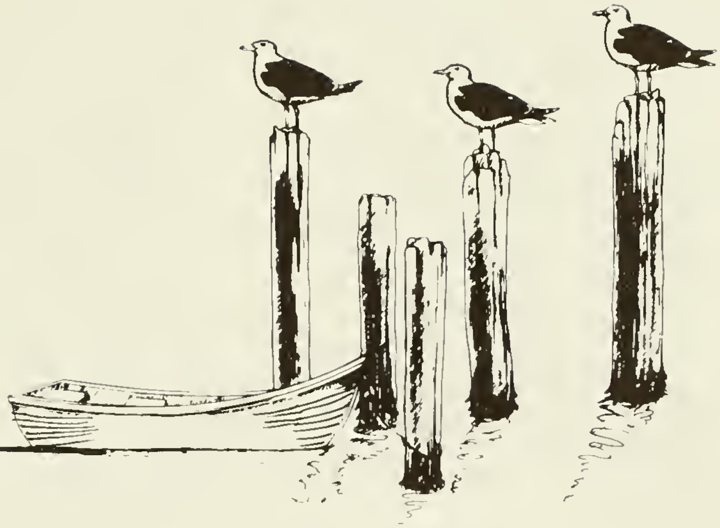
Chapter 17 Terrestrial Mammals



Author: Craig Ferris

The group of mammals discussed in this chapter, collectively termed terrestrial mammals, includes 52 species representing several diverse orders: marsupials, bats, shrews and moles, rabbits and hares, rodents, carnivores, and hoofed mammals (table 17-1). Mammals are integral components of the terrestrial systems in the characterization area and are important to humanity for economic, recreational, and aesthetic reasons. No species are endangered or threatened but many are faced with shrinking habitats because of land development along the coast; their welfare should be an important consideration for regional planners.

The term "terrestrial" mammals is not entirely correct, since several species (e.g., beaver, otter) spend much of their time in the water. The term is used to distinguish the species discussed in this chapter from the marine mammals (seals, whales and porpoises) discussed in chapter 13. Mammals use terrestrial habitats ranging from urban areas and rural farmland to mature forests and most freshwater wetlands (palustrine, lacustrine, riverine; table 17-2). Mammals interact with other animals and plants through food chains, both as consumers and as prey. They influence plant species composition and distribution by consuming seeds and plant material; and they modify entire habitats (e.g., beavers).

Forty-four species of mammals are found within all six regions of the characterization area, while eight others are found in only some of the regions (Godin 1977; table 17-3). With the exception of three species of bats that migrate south during winter, mammals are year round residents.

Many species of terrestrial mammals found along the Maine coast have a direct relationship to humanity. Ten species are hunted for sport and 13 are trapped for fur. A few species (i.e., deer, bear, raccoon) cause economic losses from crop depredations. Mammals are also of aesthetic and scientific interest to humanity. In turn, people affect mammals. People alter the amount and quality of available habitat through, logging, agriculture, development, fire, wetland drainage, and stream channelization; and directly or indirectly alter mortality rates among mammals through hunting, trapping, poisoning, and accidental killing.

Table 17-1. Mammals Known to Occur Within the Characterization Area, Listed by Order[a]

Marsupialia	Rodentia (cont.)
Virginia opossum*	Deer mouse
	White-footed mouse
Insectivora	Gapper's red-backed vole
Masked shrew	Meadow vole
Water shrew	Pine vole*
Smokey shrew	Muskrat
Thompson's pygmy shrew	Southern bog lemming
Short-tailed shrew	Norway rat
Hairy-tailed mole	House mouse
Star-nosed mole	Meadow jumping mouse
	Woodland jumping mouse
Chiroptera (Bats)	Porcupine
Little brown bat	
Keen's myotis	Carnivora
Small-footed myotis	Coyote
Silver-haired bat	Red fox
Eastern pipistrelle*	Gray fox*
Big brown bat	Black bear*
Red bat	Raccoon
Hoary bat	Marten*
	Fisher*
Lagomorpha (Rabbits and Hares)	Ermine
New England cottontail*	Long-tailed weasel
Snowshoe hare	Mink
	Striped skunk
Rodentia	River otter
Eastern chipmunk	Bobcat
Woodchuck	
Gray squirrel	Artiodactyla (Even-toed ungulates)
Red squirrel	White-tailed deer
Southern flying squirrel	Moose
Northern flying squirrel	
Beaver	

[a]Species marked with asterisk (*) are not found in all regions (See table 17-3).

Table 17-2. Amounts (square miles, except shoreline) of Major Habitat Types in Wildlife Management Units 6, 7, and 8, Which Encompass the Characterization Area[a,b]

Habitat	Wildlife management unit 6	7	8	Total
Terrestrial				
Coniferous forest	941 (37)[a]	305 (14)	688 (24)	1914 (26)
Deciduous forest	139 (05)	261 (12)	337 (12)	737 (10)
Mixed forest	-	-	38 (01)	38 (01)
Successional forest	1030 (40)	977 (46)	897 (32)	2904 (39)
Total forest	2110 (82)	1543 (73)	1940 (69)	5593 (75)
Farmland	139 (05)	277 (13)	261 (09)	677 (09)
Developed	86 (03)	120 (06)	354 (13)	560 (07)
Palustrine				
Freshwater	51 (02)	48 (02)	49 (02)	148 (02)
Saltwater	60 (02)	23 (01)	54 (02)	137 (02)
Open fresh water	128 (05)	99 (05)	151 (05)	378 (05)
Total area	2574	2110	2809	7493
Linear miles of shoreline				
Lacustrine	641	511	770	1922
Riverine	3259	2616	2530	8405

[a]Numbers in brackets are percentages of unit totals.
[b]Adapted from Anderson et al. 1975[a].

Table 17-3. Regional Distribution of Species of Mammals Not Found in All Regions of the Characterization Area[a]

Species	Regions 1	2	3	4	5	6
Virginia opossum	X					
Eastern pipistrelle	X					
New England cottontail	X	X	X			
Pine vole	X					
Gray fox	X	X	X	X		
Black bear				X	X	X
Marten				X(?)	X(?)	
Fisher		X	X	X		

[a]Godin 1977.

The purpose of this chapter is to familiarize the reader with the ecological relationships of mammals within ecosystems along the coast, to describe the effects of people on mammals, and to provide information to help lessen adverse effects. Species found in specific regions, the habitats in which each species is likely to be found, and the abundance of the different habitat types important to mammals are addressed first. Following is a discussion of the the ecological relationships of mammals, the role of mammals in their communities, and the natural factors affecting abundance. These provide a background for a description of the effects of people on mammals, which is followed by a discussion of the importance of mammals to humanity. Finally, a summary is given of some management procedures that can be used to mitigate the detrimental effects of human activity. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

DATA SOURCES

The information used to prepare this report came from books, published research reports, theses, personal communications, and unpublished manuscripts. The latter includes species management plans, which have been prepared by the Maine Department of Inland Fisheries and Wildlife (MDIFW) on most species of game and furbearing mammals. These plans provide historical perspectives, estimates of current populations, demand by hunters and trappers, current harvest levels, and habitat preference and abundance. Most of the information contained in species management plans is summarized on the basis of Wildlife Management Units (WMU), which are designated areas within which uniform wildlife management practices are appropriate. Wildlife Management Units 6, 7, and 8 contain most of the characterization area (figure 17-1) but extend farther inland so that some information may not represent the coastal area in detail. In many instances no other information is available. Points at which the data becomes less representative of the immediate coast will be noted. Unit 6 is perhaps best representative of the corresponding characterization regions (5, 6, and part of 4), since 64% of Unit 6 lies within the characterization area. Forty-nine percent of Unit 7 (regions 2, 3, and 4) and only 8% of Unit 8 (regions 1 and 2) lie within the characterization area.

DISTRIBUTION AND ABUNDANCE

The abundance of each species varies regionally, due primarily to the amounts of suitable habitat available. This section discusses general distribution and abundance of mammals in the six regions, describes the specific habitat preferences of each species, and summarizes the availability of those habitats along the coast. Finally, population estimates are given for selected game and furbearing species, based on habitat quantity and species densities for those habitats.

Regional Distribution

Forty-four species (85%) of mammals are found in all six regions of the characterization area (table 17-1). It is difficult to delineate the exact boundaries of a species' range, particularly if the range is changing. At the edge of a species' range populations are usually low and the number of observations of the species, on which the range is based, is low. This is confounded by the natural fluctuations that all species undergo. For species with very low numbers these fluctuations may cause the population to disappear altogether. The result is a constantly changing boundary, based on population levels. The distributions presented in table 17-3 are based on published data and, while they are the best available information to date, they should not be regarded as absolute.

Five species of mammals are found only in the southern regions and reach the northern limits of their distribution within the characterization area: Virginia opossum, eastern pipistrelle, New England cottontail, pine vole, and gray fox. All but the pipistrelle (a bat) are expanding their ranges northward. The opossum seems to be limited by cold temperatures, because its fur is a poor insulator and it must remain in its den during severe winter weather (Scholander et al. 1950; and Godin 1977). Populations of the New England cottontail are increasing and the range is expanding, perhaps in response to changes in habitat. Because the cottontail is the preferred prey of the gray fox, it, too, is increasing (Palmer 1956; and Stanton 1960).

Three other species are absent from portions of the characterization region: black bear, marten, and fisher (table 17-3). The black bear is fairly abundant in eastern Maine (regions 5 and 6) but is scarce in regions 3 and 4 and absent from regions 1 and 2. Marten were formerly found in much of Maine but were reduced by trapping and habitat loss (Coulter 1959). Recently they have been expanding their range eastward and southward and may be present in the northern extensions of regions 4 and 5. Fishers are abundant in the mid-coast area (regions 3 and 4) but have never been numerous east of the Penobscot River. They may be absent from along the coast in extreme southern Maine because of the lack of suitable habitat.

Figure 17-1. Relationship between wildlife management units and the characterization regions in coastal Maine (Maine Department of Inland Fisheries and Wildlife 1974).

Excluding the eight species mentioned above, each species of terrestrial mammal should be present in suitable habitat throughout the characterization area, with the exception of the offshore islands. Expanses of salt water present a formidable barrier to most species of mammals, so they are absent from all but the nearest or largest offshore islands. Mammals reach islands by swimming, rafting on debris, crossing ice bridges, or by coming with people. Two deer reportedly swam over 2 miles (3.2 km) and another swam nearly 7 miles (11.3 km) to the mainland from islands on which they had been released (Schemnitz 1975). Morse (1966) also reported deer swimming freely between Hog Island and the mainland but this was only a distance of a few hundred yards. Rafting is used most likely by small mammals that get trapped on pieces of earth or debris that break loose from the mainland during storms. Ice bridges are used by wide-ranging species such as deer, fox (Morse 1966), and raccoon. Mammals brought by people probably include mice, rats, and voles that are small enough to stow away on boats, and domestic animals (dogs, cats, sheep). Species lists of mammals present on some of the larger islands have been compiled and are summarized in appendix table 10.

Islands also present problems other than accessibility that prevent species from becoming established. Populations of colonizing species are small initially and natural fluctuations may cause their extinction (Crowell 1973). Colonizing individuals may have to compete with closely-related species that are already present. Native species seem to have an advantage in these situations, perhaps because of their larger numbers (Crowell and Pimm 1976). Some of these factors were seen among the small mammals that were studied by Crowell (1973) and Crowell and Pimm (1976) on the islands off Deer Isle (region 4). Meadow voles are the most abundant species on small islands; they seem more capable of reaching islands and they reproduce rapidly once established. Deer mice are present only on larger islands, where their populations can build up sufficiently to preclude chance extinctions. Red-backed voles seem to have a poor dispersal capability, low reproductive potential initially, and little or no ability to compete successfully with meadow voles.

Habitat Preferences

Within its geographical range each species has preferred or optimal habitats in which it will most likely be found. Each species also has less-preferred or marginal habitats in which it will be found less frequently and usually in fewer numbers (figure 17-2). Some species, such as beaver, otter, or flying squirrels, occupy only a few habitat types, while others (i.e., coyote, red fox, short-tailed shrew) inhabit a wide range of habitat types. Species with restricted habitat preferences are generally less adaptable and do not tolerate disturbance as well (Gill and Bonnet 1973). Planners need to be aware of species with restricted habitat preferences so that if these species are found within areas scheduled for development the impact of the habitat loss on their populations can be assessed. Critical habitats in a region need to be identified, and protected. The number of preferred and acceptable habitats is summarized in figure 17-2. Species that may be of concern ecologically, because of their narrow habitat preferences, are the water shrew, some of the bats, and the aquatic furbearers.

	IN OR NEAR LAKES, PONDS, RIVERS, STREAMS	MARSHES, BOGS WETLANDS	MEADOWS	SHRUBS, OLD FIELDS	EDGES (FIELD/FOREST)	DECIDUOUS FOREST	MIXED FOREST	CONIFEROUS FOREST	RURAL	URBAN	NUMBER OF PREFERRED OR ACCEPTABLE HABITATS
LAKES, PONDS, RIVERS, STREAMS											
Virginia opossum	●	●									2
Water shrew	●					●	●	●			4
Little brown bat*	●		●			○	○	○	●		7
Keen's myotis*	●		●			○	○	○	●		7
Silver-haired bat*	●					●	●	●			4
Beaver	●	●				○					3
Raccoon*	●	●			○	●	●		○	○	7
Mink	●	●				○	○	○			5
Otter	●	●									2
MARSHES, BOGS, WETLANDS											
Star-nosed mole	○	●	●								3
Muskrat	●	●									2
Southern bog lemming		●	○			○	○	○	○		6
Meadow jumping mouse	●	●	●	●							4
FORESTED UPLANDS (INCLUDING OLD FIELD)											
Masked shrew	●					●	●	●			4
Smokey shrew	○	●				●	●	●			5
Thompson's pygmy shrew	○					●	●	●			4
Short-tailed shrew	●		●	●	●	●	●	○	●		8
Silver-haired bat*	●					●	●	●			4
Eastern pipistrelle	●					●	●		○		4
Red bat					○	●			○	○	4
Hoary bat					○	○	○	●	○	○	6
New England cottontail			○	○	○	●	●	●			6
Snowshow hare				●	●	●	●	●			5

● preferred ○ acceptable

Figure 17-2. Habitat preferences of terrestrial mammals found in the characterization area (after Godin 1977).

(Continued)

	IN OR NEAR LAKES, PONDS RIVERS, STREAMS	MARSHES, BOGS, WETLANDS	MEADOWS	SHRUBS, OLD FIELD	EDGES (FIELD-FOREST)	DECIDUOUS FOREST	MIXED FOREST	CONIFEROUS FOREST	RURAL	URBAN	NUMBER OF PREFERRED OR ACCEPTABLE HABITAT
FORESTED UPLANDS											
Eastern chipmunk				○	●	●	○		○	○	6
Gray squirrel					○	●	●		○	○	5
Red squirrel					○	○	○	●	○		5
Northern flying squirrel							●	●			2
Southern flying squirrel	○					●	○		○		4
Deer mouse					○	●		●	○		4
White-footed mouse				●	●	○	○				4
Red-back vole							○	●			2
Pine vole		○	●			●	●	●			5
Woodland jumping mouse	●					●	●	●			4
Porcupine						○	●	○			3
Coyote		○		●	●	●					4
Red fox			●	●	●	●	●		○		6
Gray fox				○	○	●	●				4
Black bear	○	○				○	●	○			5
Raccoon*	●	●			○	●	●		○	○	7
Marten							○	●			2
Fisher					○	○	●	○			4
Ermine	○			●	●						3
Long-tailed weasel	○			●	●	○					4
Striped skunk			●	●	●				○		4
Bobcat			○	○	●	●	●	●	○		7
White-tailed deer	○	○		●	●	○	○	○	○		8
Moose	●	●			○	○	○	○			6

● preferred ○ acceptable

Figure 17-2. (Continued)

	IN OR NEAR LAKES, PONDS RIVERS, STREAMS	MARSHES, BOGS WETLANDS	MEADOWS	SHRUBS OLD FIELD	EDGES (FIELD-FOREST)	DECIDUOUS FOREST	MIXED FOREST	CONIFEROUS FOREST	RURAL	URBAN	NUMBER OF PREFERRED OR ACCEPTABLE HABITAT
AGRICULTURAL LANDS											
Short-tailed shrew*	●		●	●	●	●	●	○	●		8
Hairy-tailed mole			●			●	●				3
Woodchuck	○		●	●	●	○			○		6
Meadow vole	○	○	○	○	○	○			○		7
Pine vole*		○	●			●	●	●			5
House mouse*			○						●	●	3
Meadow jumping mouse*	●	●	●	●							4
Red fox*			●	●	●	●	●		○		6
RURAL AND URBAN LANDS											
Little brown bat*	●		●			○	○	○	●	○	7
Keen's myotis	●		●			○	○	○	●	○	7
Small-footed myotis									●	○	2
Big brown bat									○	○	2
Norway rat	○	○							●	●	4
House mouse*			○						●	●	3
TOTAL NUMBER OF SPECIES PER HABITAT	27	17	14	16	23	38	33	26	23	11	

● preferred ○ acceptable * - appears more than once on the chart

Figure 17-2. (Concluded)

At the other end of the spectrum are species that occupy a wide range of environments. Generally, these species have adapted to human presence and can often thrive in altered habitats. These species are less likely to be eliminated through habitat alteration.

A few species have seasonal habitat preferences, or requirements; consequently more than one habitat must be available within the home range of individual animals. For example, deer require dense coniferous forest in winter, because it provides reduced snow depth and protection from wind (Glasgow 1949; Gill 1957; and Day 1963). Deer concentrate in particular locations within this habitat type year after year during severe winter conditions. The locations of many of these areas, called deer "yards", are known and are plotted on atlas map 4. Since most of the coastal zone is subject to severe winters periodically (Banasiak and Hugie 1975), this habitat type must be preserved in sufficient quantity and distribution to ensure survival of deer. Coniferous forest provides little food, so habitats that contain abundant herbaceous and woody browse (such as old fields, second growth hardwoods, meadows, and wetlands) are needed. Adequate year-round deer habitat must include a mixture of both of these types of habitat in close proximity. This illustrates the concept of interspersion of habitats, which is very important for species of wildlife that require more than one habitat type. If necessary habitats are not present within the home range or cruising radius of a mammal, it cannot survive. Therefore, a sufficient amount of a particular habitat type on a regional basis is not enough. If a habitat exists in large uniform blocks it will not be suitable for those species requiring an interspersion of two or more habitats. Size must be considered in relationship to the home range of each species. For small mammals (mice, shrews, voles) an area of 10 to 15 acres (4 to 6 ha) would far exceed the normal home range of an individual, while foxes or coyotes may range over an area of several square miles. Banasiak and Hugie (1975) regard the degree of interspersion of habitats relative to deer (which range 1/4 to 1/2 mile; 0.4 to 0.8 km) as moderate in regions 5 and 6 and high in regions 1 to 4. Black bears, which also require several habitat types, range over a much larger area, as much as 20 sq mi (51 sq km) or more. Within their home range they require township-sized blocks (36 sq mi; 92 sq km) of forest habitat. These conditions are not present in regions 1 to 4 of the characterization area, which is one reason that black bears are not abundant there (Hugie and Banasiak 1975).

The relative importance of each community type to mammals as a group is indicated by the total number of species utilizing each type (figure 17-2). All species of mammals found within the same habitat may be said to constitute the "mammal community" of that habitat. Forest systems (deciduous, coniferous, and mixed) and aquatic habitats (palustrine, lacustrine, and riverine) are preferred habitat for the greatest numbers of species and acceptable habitats for many others. Urban areas and open meadows support fewest species. Land development on shorelines and watercourses, draining wetlands, and removing forest habitat has a greater impact on mammals, in terms of the number of species affected, than alterations in other habitats. On the other hand, providing small patches of these habitats, particularly forests and wetlands, within urban areas can increase the diversity of mammal communities significantly (Leedy et al. 1978).

ROLE OF MAMMALS IN THE ECOSYSTEM

Mammals have a major role in their communities, primarily in the transfer of energy and nutrients through food chains. As a result of their role mammals can sometimes exert significant influences on other groups within their communities. Herbivores may assist in the distribution of plants by disseminating seeds or limit the distribution of other plants by overutilizing them. Carnivores may influence the abundance of their prey and beavers can alter entire communities to their liking. Knowledge of the food habits of mammals is important for an understanding of the effects of people on mammals, because people can affect mammals indirectly through their food supply. For example, spraying a forest stand to control spruce budworm may reduce populations of other insects that serve as food for small mammals.

Mammals found within the characterization area range from strict herbivores (e.g., deer, moose, snowshoe hares), which consume only plant material, to insectivores (e.g., bats and shrews), and carnivores (e.g., bobcat and otter) that rely solely on invertebrates or meat, respectively. The majority of species, however, are omnivorous; that is, they consume both plant and animal matter. The food preferences of the mammals found in coastal Maine are shown in figure 17-3. The role of herbivores is to convert the energy stored in plants into animal tissue. Mammals that consume twigs, stems, and bark (e.g., deer, moose, hares) have special adaptations in their digestive systems (rumen or large caeca) and host symbiotic microorganisms that aid the breakdown of complex structural carbohydrates (cellulose and lignin) and release the energy stored in chemical bonds. Other herbivores do not possess this ability and consume more digestible plant material, such a fruits, seeds, nuts, leaves, and tender shoots.

Usually only a relatively small amount of the total plant material in a community is consumed by mammals. Browsing mammals can kill individual plants by repeated cropping of twigs, stems, and foliage. For example, heavy browsing by deer on Canada yew has virtually eliminated this plant from portions of its former range in New York. In the northern hardwood forests of the Adirondack Mountains, deer have caused a shift in the plant species composition by selectively browsing maple, birch, and ash seedlings, which allowed the less desirable beech to become dominant in the understory (Tierson et al. 1966). Areas protected from deer had a more even distribution of plant species. Herbaceous vegetation showed similar effect. Biologists have recognized the ability of certain plants, such as mountain maple, to withstand repeated cropping of current growth and still survive. These plants can be encouraged where food production for browsing animals is desired.

Small mammals can affect the regeneration of plants by eating seeds or nuts. Squirrels can consume the entire crop of acorns or hickory nuts in most years. However, during the occasional years with "bumper" crops, enough seeds escape to ensure sufficient regeneration (Barnett 1977).

Sometimes mammals aid the dispersal of plants by consuming fruits and later passing the seeds in their feces. In the characterization area, bears, raccoons, foxes, and other mammals distribute the seeds of such plants as raspberries and cherries in their feces and beggars ticks in their fur. Recent research in New Hampshire suggests that gray squirrels are perhaps the most important factor affecting establishment of white pine regeneration

● preferred

○ acceptable

	NUTS, FRUITS, BERRIES, SEEDS, FLOWERS, ETC.	WOODY PLANTS: STEMS, CONES, BARK, ROOTS, ETC.	HERBACEOUS PLANTS: GRASS, FERNS, HERBS	FUNGI, MUSHROOMS	TERRESTRIAL INVERTEBRATES	AQUATIC INVERTEBRATES	REPTILES AND AMPHIBIANS	FISH	BIRDS	SMALL MAMMALS	MEDIUM-SIZED MAMMALS	LARGE MAMMALS	CARRION	NUMBER OF PREFERRED OR ACCEPTABLE FOODS
HERBIVORES														
New England Cottontail		●	●											2
Snowshoe hare		●	●											2
Woodchuck		●	●		○									3
Beaver		●	○											2
Meadow vole	○	●	●											3
Pine vole	●	●			○									3
Southern bog lemming		○	●	○	○									4
Muskrat			●			○	○	○	○				○	6
Porcupine	●	●	●											3
White-tailed deer	○	●	●	○										4
Moose		●	●	○										3
OMNIVORES														
Virginia opossum	●	○	○	○	●	●							●	7
Short-tailed shrew	○				●	○	○		○	○			○	7
Eastern chipmunk	●	●	●	●	○		○		○	○				8
Gray squirrel	●			●	○				○					4
Red squirrel	●	●	○	○	○				○	○				7
Northern flying squirrel	●			○	○				○	○				5
Southern flying squirrel	●			○	○				○					4
Deer mouse	●				●								○	3
White-footed mouse	●				●								○	3
Red-backed vole	●	○	●	●	○									5
Norway rat	○						○	○	○	○	○		○	7
House mouse	○				○									2
Meadow jumping mouse	●			●	●									3
Woodland jumping mouse	●		●	●	●									4
Coyote	○				○	○	○	○	○	○	○	○	●	10

Figure 17-3. Food preferences of terrestrial mammals found in the characterization area (Godin 1977).

(Continued)

● preferred

○ acceptable

	NUTS, FRUITS, BERRIES, SEEDS, FLOWERS, ETC.	WOODY PLANTS: STEMS, CONES, BARK, ROOTS, ETC	HERBACEOUS PLANTS: GRASS, FERNS, HERBS	FUNGI, MUSHROOMS	TERRESTRIAL INVERTEBRATES	AQUATIC INVERTEBRATES	REPTILES AND AMPHIBIANS	FISH	BIRDS	SMALL MAMMALS	MEDIUM-SIZED MAMMALS	LARGE MAMMALS	CARRION	NUMBER OF PREFERRED OR ACCEPTABLE HABITAT
OMNIVORES														
Red fox	●				●		●		●	●			●	6
Gray fox	●				●		●		●	●			●	6
Black bear	●				●		●	●		●			●	6
Raccoon	●				●	●	●		●	●			●	7
Skunk	●				●		●		●	●			●	6
INSECTIVORES														
Masked shrew						●		○						2
Water shrew	○				●								○	3
Smokey shrew					●		○		○	○				4
Pygmy shrew					●								○	2
Hairy-tailed mole					●									1
Star-nosed mole						●		○						2
Little brown bat					●									1
Keen's myotis					●									1
Small-footed myotis					○									1
Silver-haired bat					●									1
Eastern pipistrelle					●									1
Big brown bat					●					○				2
Red bat					●									1
Hoary bat					●					○				2
CARNIVORES														
Marten	○				○		○	○	○	●			○	7
Fisher	○				○		○	○	○	●	●		●	8
Ermine					○		○		○	●	●		○	6
Long-tailed weasel					○		○		○	●	●		○	6
Mink						●	●	●	○	●	●		○	7
River Otter						●	●	●	○					4
Bobcat					○	○	○		○	○	●	●	○	6

Figure 17-3. (Concluded)

(personal communication from L. Alexander, Forestry Department, University of New Hampshire, Durham, NH.; February, 1979). Squirrels digging under oaks and hickories expose mineral soil that is required for germination of white pine seeds.

Insectivorous or carnivorous mammals consume a wide variety of animal tissue, including insects and other invertebrates, fish, reptiles and amphibians, birds, and other mammals (figure 17-3). Mammals in turn are preyed upon by fish (e.g., bass), reptiles (snakes and turtles), and birds (hawks and owls).

Just as there are habitat generalists and specialists among mammals there are also diet generalists and specialists. Some generalists are the coyote, fox, raccoon, black bear, and opossum. Specialists include the bobcat, water shrew, and most bats. Diet specialists are more susceptible to disruptions in their food supply, both natural and human-induced, because they are not capable of changing to other food sources if their preferred food is not available. Diet specialists are also vulnerable to the effects of pollution and pesticides, because if their food becomes contaminated they may acquire large concentrations through repeated small doses.

Beavers have a unique role in their communities. Beaver dams create habitat for many other species of mammals, as well as fish, reptiles, amphibians, invertebrates, and birds. Beaver flowages are particularly important for moose (Dunn et al. 1975) and are used by deer (Banasiak and Hugie 1975), bear (Hugie and Banasiak 1975), and aquatic mammals (e.g., muskrat, mink, otter, etc.).

FACTORS OF ABUNDANCE

The distribution and abundance of mammals on a regional basis is affected most by the amount and quality of their preferred habitats. There are no data on habitat availability within the six characterization regions but information does exist for the three Wildlife Management Units that encompass the coastal zone. A summary of the major habitat types is presented in table 17-2, while a more detailed description can be found in appendix tables 1 to 9. Overall, 75% of the total area of Wildlife Management Units 6, 7, and 8 is covered with forest habitat, ranging from 69% in Unit 8 to 82% in Unit 6. While this is less than the overall State total of 90% (Ferguson and Kingsley 1972), there unquestionably is an abundance of forest habitat. The combined amount of urban and rural land constitutes 16% of the total area, ranging from 8% in Unit 6 to 22% in Unit 8. Since the majority of developed land is along the immediate coast, the proportion within the characterization area is much higher. Open fresh water (lakes and ponds) constitutes 5% of the area, and wetlands (both fresh and saltwater) occupy only 3% to 4%.

The importance of a habitat type to mammals usually should not be judged on the basis of acreage alone. As was pointed out earlier, wetland habitats support some of the most diverse mammal communities and yet constitute only a small portion of the total characterization area. Habitats such as these that are in short supply are often critical for the survival of some species.

In order to show how these habitat figures relate to animal abundance, table 17-4 summarizes the available habitat, species densities (animals per unit of habitat), and total populations for a number of game and furbearing species in each of the three Wildlife Management Units along the coast. These data were obtained from species management plans, described earlier, and are approximations at best. The data concerning animal densities, in particular, should be considered only as very rough approximations, and only be used for comparing relative abundance between regions. More detailed data are available in appendix tables 1 to 9. In most instances the density figures are different for each of the three units, because the total habitat figure is made up of differing amounts of habitat types, each with a corresponding density figure. Also, animal abundance in the same habitat may vary from one unit to the next, because of the quality of the habitat, its interspersion with other required types, its positon in the species range, or other factors described below.

Natural Factors Affecting Abundance

A unit of habitat is capable of supporting only a given number of individuals of one species. This is often called the carrying capacity of the habitat. The size of a population results from increases due to birth and immigration and losses due to death or emigration. For populations below carrying capacity, gains usually exceed losses and the population increases. As it approaches saturation levels, several factors can enter to reduce population growth by affecting reproductive rates, increasing mortality, or increasing emigration.

Each species has a maximum inherent reproductive rate, which is determined by (1) the number of young per litter, (2) the number of litters per year, and (3) the minimum age of first breeding (appendix table 11). Some species (e.g., bats, black bears) have low rates of reproduction, producing only one or a few young each year. Others, like the meadow vole, are capable of producing up to 40 to 50 young in a single year. Species with high reproductive potentials are capable of rapid population increases following depletion of their numbers or upon encountering unoccupied habitats. Conversely, species with low reproductive rates will rebound slowly from reductions in population size and are therefore more susceptible to exploitation.

Reproductive rates may be reduced to a level lower than their maximum potential by inadequate nutrition. Deer on poor range have a lower incidence of twins or triplets, and first year does on poor range are less likely to produce fawns than deer on good range. Snowshoe hares, mice, and voles may have fewer litters per season, as well as a delay until first breeding, due to food shortage. Social stress, brought about by high population densities, may have similar consequences. The mechanics of stress are not entirely clear, but apparently, increased contacts between individuals causes changes in hormone levels that in turn affect reproduction.

Territorial behavior also limits the density of animals in a given unit of habitat. Many species, including mice, beavers, and most carnivores, are territorial and individuals exclude other members of their species from the particular area they occupy. This limits population size by (1) spacing out individuals, (2) reducing immigration, and (3) preventing some individuals from breeding. Young produced within a territory are tolerated until they become independent, at which time they are forced to disperse. If these individuals are not able to establish a territory in some other part of the habitat they may become part of a floating, nonbreeding segment of the population, which wanders from one territory to the next until a vacant area is found.

This dispersal is an important mechanism of population regulation for many species of mammals (e.g., bears, voles, hares, beavers). The fate of dispersing individuals is (1) they settle in unoccupied territories when available, (2) they try to survive in suboptimal habitats, or (3) they die from lack of suitable habitat. Dispersing individuals suffer higher mortality from predation and accidents than resident animals because they are less familiar with their surroundings and their increased movement brings them into contact with a greater number of hazards (Ambrose 1977).

Species of mammals that are not territorial, such as deer and moose, do not possess a dispersal mechanism for controlling abundance. Although passive dispersal may occur populations that are increasing continue to do so until some resource, usually food, becomes limiting. Mortality from starvation usually occurs during the winter, when energy requirements are highest. This may be due to inadequate food supplies in late summer or fall when fat stores necessary for winter survival must be built up. Winter mortality can be an important mechanism of control for deer populations in Maine. Mild winters allow the population to increase above the ability of the habitat to support it through normal winters. Widespread deaths then occur when normal or severe winters follow. This is illustrated by the deer harvest in the coastal regions, which, when adjusted for season length and hunting effort, reflects the status of the deer population. Figure 17-4 shows the adjusted harvest of deer in each of the six coastal regions for the years 1959 to 1977. In almost all instances the harvest is low after severe winters and high after mild winters. This is complicated in some cases (i.e., 1973 and 1976) when mild winters were followed by hunting seasons in which poor hunting conditions existed due to lack of tracking snow.

Mammals experience other forms of mortality such as predation, diseases, parasites, and weather-related mortality. The importance of these factors among mammal populations along the coast of Maine generally is unknown. The importance of natural predation in controlling small mammal populations has been studied extensively outside Maine. Some authors (Craighead and Craighead 1969) have suggested that predation can control populations but it is generally accepted that predation alone is not sufficient (Pearson 1964; and Errington 1963). Keith (1974), studying the 10-year cycle of snowshoe hares in Alberta, has shown that predation can keep numbers low after they have declined (crashed), but it is not responsible for the significant rapid population declines (which may be due to food shortage caused by overpopulation).

Predation has been shown to be important in controlling populations of some large mammals, such as moose in Michigan (Mech 1966) and Dall sheep in Alaska (Murie 1944). In Maine, however, there are no serious predators of moose or deer and losses due to bobcats, coyotes, and dogs seem to be relatively low. During the years 1969 to 1977 an average of 256 deer and less than one moose were reported killed by predators. These figures do not represent total losses for the entire State but only reported losses.

Table 17-4. Available Habitat, Species Densities, and Total Population Estimates for Selected Species of Game and Furbearing Mammals in Wildlife Management Units 6, 7, and 8[a, b, c]

Species	Wildlife management unit 6	7	8	Total
Aquatic furbearers				
Beaver				
Habitat (stream miles)	1375	1062	1027	3464
Density/100 miles	115	104	81	102
Total population	1575	1109	834	3518
Mink				
Habitat (miles of shore and stream)	3900	3127	3300	10,327
Mink/100 miles	60	51	27	47
Total population	2352	1604	900	4856
Muskrat				
Habitat (sq. mi)	50	43	60	153
Muskrat/sq. mi.	514	881	810	733
Total population	25,700	37,900	48,600	112,200
Otter				
Habitat (miles)	3900	3127	3300	10,327
Otter/1000 miles	90	84	59	79
Total population	353	262	196	811
Upland furbearers				
Fisher				
Habitat (sq.mi.)	2121	1546	1896	5563
Fisher/10 sq. miles	<1	15	9	7
Total population	30	2320	1680	4030
Marten				
Habitat (sq.mi.)	226	66	92	384
Density	-	-	-	-
Total population	-	-	-	-

[a]Wildlife management units 6, 7, and 8 encompass the chacterization area.
[b]From Anderson et al. 1975 a,b,c, and d.
[c]Counts 1 stream mile = 1 acre habitat.

(Continued)

Table 17-4. (Concluded)

Species	Wildlife management unit 6	7	8	Total
Upland furbearers (cont.)				
Bobcat				
Habitat (sq.mi.)	2110	1541	1902	5553
Density/100 sq.mi.	22	13	8	15
Total population	464	199	148	811
Coyote				
Habitat (sq.mi.)	2312	1845	2176	6333
Density/100 sq.mi.	13	11	11	12
Total population (*potential)	290	210	240	740
Red fox				
Habitat (sq.mi.)	2345	2429	2209	6983
Density/100 sq.mi.	77	66	78	73
Total population	1802	1606	1714	5122
Raccoon				
Habitat (sq.mi.)	695	1163	1799	3657
Density/sq.mi.	8	9	9	9
Total population	5900	9900	15,400	31,200
Big Game Species				
White-tailed deer				
Habitat (sq. miles)	2207	1649	1986	5842
Deer/10 sq. miles	27	105	96	89
Total population	16,000	17,000	19,000	52,000
Moose				
Habitat	2223	1615	1964	5802
Moose/100 sq. miles	14	13	10	12
Total population	311	210	196	717
Black bear				
Habitat	1670	75	100	1845
Bear/100 sq. miles	38	35	30	38
Total population	646	26	30	702

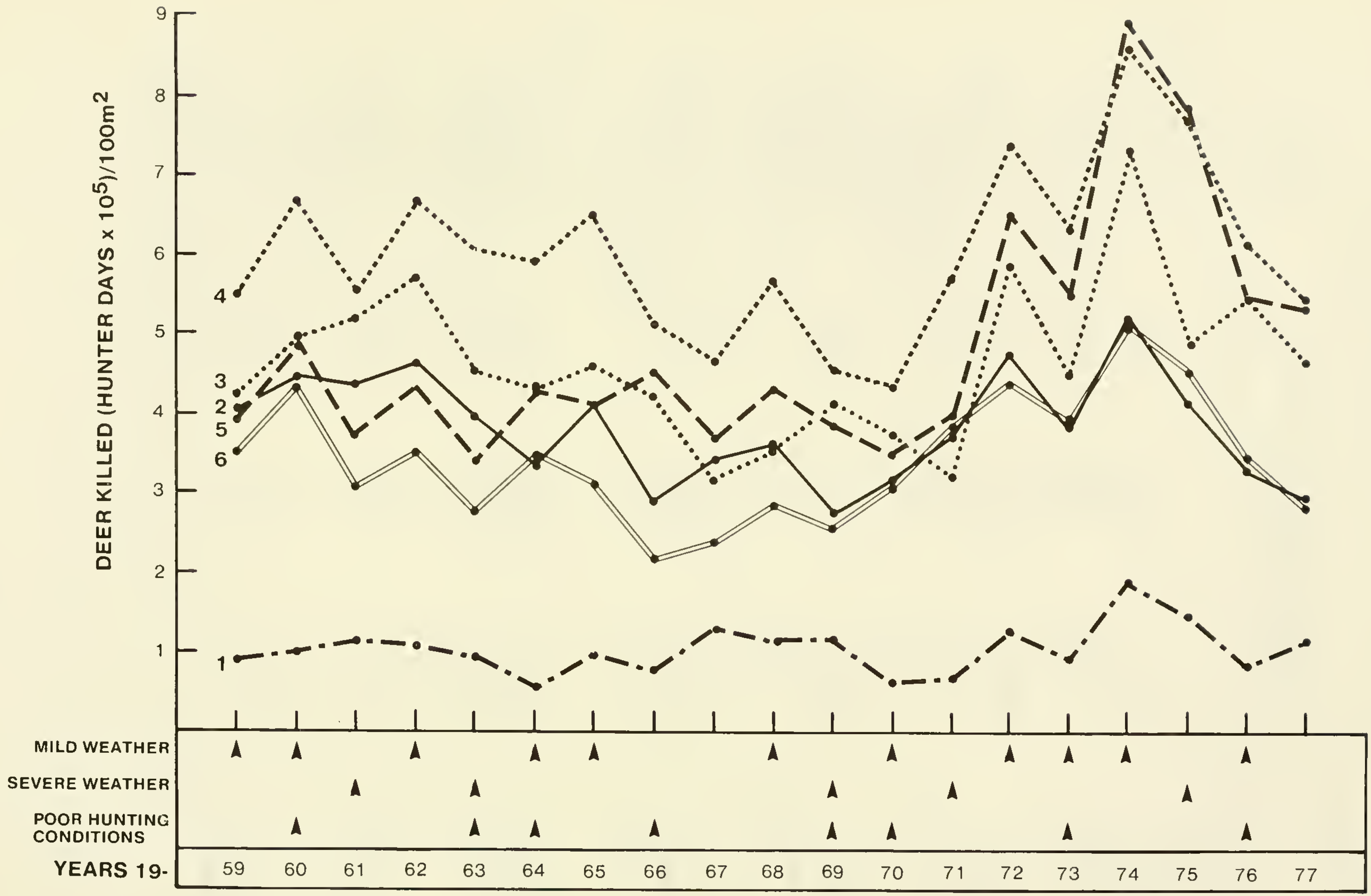


Figure 17-4. Relationship between previous winter conditions (based on the winter severity index) and the harvest of white-tailed deer in the six regions, adjusted for length of hunting season and number of hunters.

The role of diseases and parasites is occasionally of some significance to mammals in Maine. The most important example is the brain worm parasite (Paraelaphostrongylus tenuis) and its effect on moose populations. The natural host of the brain worm is the white-tailed deer, in which it apparently causes no harm. However, it is also capable of infecting moose when it is ingested with its alternate host, one of several species of molluscs. The brain worm damages the central nervous system, sometimes killing moose outright but also affecting their behavior, which subjects them to other forms of mortality (such as roadkills, poachers, and accidents). Gilbert (1974) studied the incidence of brain worm in Maine moose and found that where moose occurred with high deer populations the rate of infection was high enough to reduce moose populations significantly. The incidence of brain worm in a sample of illegally killed moose was 50%, 80%, and 64% in Wildlife Management Units 6, 7, and 8, respectively.

Other diseases and parasites that are important to mammals are rabies virus in carnivores (fox, skunk, coyote, bobcat) and sarcoptic mange caused by mites,(Acari). These may become manifest when host populations are high because they are transmitted more easily then and overpopulation often results in less vigorous animals that are more susceptible to infection (see below for incidence of rabies in the characterization area).

Human Factors

People affect mammals directly, through mortality factors such as hunting, trapping, roadkills and environmental contaminants, and by affecting the amount and quality of habitat that is available. In any situation involving habitat change some species will be adversely affected, and others will benefit.

The major land uses influencing mammal habitat in the characterization area are logging, agriculture, and development (housing, industrial, commercial, highways). The latter has the most significant impact because the habitat loss is permanent and developed areas support very few mammal species (figure 17-2). On the basis of Wildlife Management Units, developed land is most abundant in the southwestern coastal regions. In Wildlife Management Unit 8, 13% of the land falls in this category, compared to 6% of Unit 7 and only 2% of Unit 6 (table 17-2). Species of mammals that can be expected to benefit from further urbanization include some species of bats, gray squirrels, Norway rats, house mice, and perhaps raccoons (figure 17-2). Additional species that may benefit from suburban or rural developments (farms) include foxes, skunks, chipmunks, short-tailed shrews, woodchucks, meadow voles, and coyotes. Most other species, if not all, will be adversely affected by land development.

Although little can be done to slow the rate of urbanization, steps can be taken to mitigate its environmental effects. Habitats to be replaced should be those that are most abundant, such as forest habitats, and not those in short supply, such as wetlands. If possible, new developments should be located where old ones have been allowed to deteriorate so no net loss of habitat results. The welfare of mammals should be made an important aspect of the planning stages, so that allowances can be made to leave parks and patches of habitat and to provide corridors between these patches (Leedy et al. 1978). In the recent past the loss of habitat to development in Wildlife Management Units 7 and 8 was compensated by increases from farmland abandonment (Banasiak and Hugie 1975). This trend is not expected to continue, however, as losses will exceed gains in the future. Unit 6 is expected to maintain its present habitat composition.

Land development includes roads, highways, and power lines. The effects of these developments on mammals have been studied in Maine (Ferris 1977 and Palman 1977) and elsewhere (Michael 1975; and Schrieber and Graves 1977), and generally are limited to loss of habitat. Some evidence exists that fishers may shy away from habitat adjacent to highways (Palman 1977) and this response might be expected from other species that are easily disturbed by human presence (e.g., bears, marten, and bobcat). Oxley and his colleagues (1974) felt that four-lane highways were a barrier to movements of small mammals but additional evidence of this is lacking. Schrieber and Graves (1977) studied the movements of small mammals across power lines in New Hampshire and found that neither 164 feet (50 m) nor 328 feet (100 m) wide rights-of-way prevented movements of white-footed mice or short-tailed shrews. The concern of planners with regard to highways and transmission lines should be to place them through habitats that are least desirable for mammals (Leedy et al. 1978).

Agricultural land is most abundant in the mid-coast regions. Thirteen percent of Wildlife Management Unit 7 is agricultural, compared with 9% of Unit 8 and only 5% of Unit 6 (table 17-2). Land in production is primarily crop land, pasture land, and blueberry barrens. These lands may be used by mammals as feeding areas, particularly if individual fields are small and interspersed with forest land, abandoned fields, or hedgerows that provide cover. Agricultural lands are least desirable when they encompass large uniform tracts providing a minimum amount of edge habitat and interspersion of habitats.

Logging is most significant in regions 5 and 6 where commercial timber operations still exist. Habitat modifications resulting from timber harvesting range from very slight in single-tree selection to severe in clearcutting. However, recent increases in firewood consumption will result in more intensive harvesting on small forest lands in all regions of the characterization area.

The effects of timber harvesting on mammals have been studied since 1974 in a section of northern Maine near Moosehead Lake. This area lies well north of the characterization area but the conclusions are applicable here and anywhere that similar logging practices are employed. The results indicate that the effects on a particular species depend on the extent to which its preferred habitat is increased or decreased by the logging operation. For example, populations of the marten, a species preferring mature softwood and softwood-dominated mixed forests, were reduced 65% to 75% in an area subjected to commercial clearcutting, but were unaffected by a partial cut (Soutiere 1978). In the clearcut area marten moved freely through cuts and hunted in them; however, they used residual uncut softwood patches and partial cut hardwood stands more frequently.

Moose, on the other hand, responded favorably to clearcutting near Moosehead Lake (Burgason 1977; Monthey 1978; and Schoultz 1978). Schoultz (1978) reported that moose preferred clearcut softwood stands, followed by partial cut mixed stands and uncut forest. He attributed this to the availability of browse in clearcuts. This supports the findings of Stone (1977) that production of all classes of vegetation (herbaceous, raspberries, hardwood and softwood browse) was higher in clearcuts than in uncut habitats. The amount and quality of this vegetation are sometimes affected by the age of the clearcut. Burgason (1977) found that lands cut 20 to 25 years before were used more than those cut only 6 to 10 years before. He attributed this to a better combination of food and cover in the prior cut lands.

Deer populations usually respond favorably also to increases in herbaceous and woody vegetation following clearcutting. However, in the area studied by Schoultz (1978) access to cuts was limited during the winter by deep snow. Deer were forced into areas with dense softwood cover where snowfall is intercepted by the canopy. Only those areas of the cutover lands directly adjacent to softwood patches could be utilized for food in winter.

Thus, while populations of species that require mature forests may be reduced significantly in areas subject to clearcutting, other species will find ideal conditions in the successional stages following cutting. To minimize the effects of logging on mammals it is perhaps best to leave a mosaic of cut and uncut areas, which provides a diversity of habitats.

Another aspect of logging that affects mammals is reforestation. In the characterization area this includes the planting of seedlings and the use of herbicides. The aim of reforestation efforts by the commercial paper industry is to establish coniferous regeneration as rapidly as possible (see chapter 19, "Commercially Important Forest Types"). Herbaceous and hardwood regeneration may compete successfully with the seedlings of desirable species and may dominate a site for many years. Herbicides are sometimes used to kill the competing hardwood and herbaceous vegetation. Unfortunately these "weed" species, as they are called by foresters, are also the most beneficial species for wildlife in terms of food production. Eliminating them from large tracts of regenerating forest land will obviously affect mammal populations as well, although these effects have not been measured.

An important cause of habitat alteration, albeit unintentional, is fire. The extent to which the habitat is changed depends on the severity of the fire. Cool fires remove dead vegetation and accumulated litter, release nutrients, and often result in enhanced production of herbaceous and woody vegetation within a few weeks. Severe fires, on the other hand, destroy not only litter but also the organic matter in the soil. All vegetation may be killed and excessive soil erosion often results because there is no vegetation to hold the soil. In such cases it may be years before the site is suitable for wildlife.

Direct mortality. In addition to affecting mammal habitat people also kill mammals. Some of this is intentional, such as hunting and trapping, and is controlled so as not to reduce populations excessively. Other forms are either unintentional (e.g., roadkills) or are hard to control (e.g., illegal hunting and dogs).

Ten species of mammals are hunted for sport in Maine: deer, bear, snowshoe hare, squirrel, fox, coyote, bobcat, raccoon, woodchuck, and New England cottontail. Each deer and bear legally harvested must be tagged and recorded at an official State check station. This provides accurate harvest data for these two species. The average annual legal harvest of deer for the years 1959 to 1977 is summarized in table 17-5 for each of the six regions. The highest kill occurred in region 4 where an average of 2094 deer were killed each year. More importantly for comparative purposes, the highest kill per square mile (2.3) also occurred there. The lowest kill (89) and kill per square mile (0.4) was in region 1. This is to be expected as much of this region is urban (Portland and South Portland) and is not optimal deer habitat. Hunting losses constitute a significant portion of the annual mortality for deer populations. Depending on the productivity of the population, deer in Maine can withstand an all-cause removal of 25% to 35% (Banasiak and Hugie 1975). Present harvest levels are approximately equal to the removable supply. The all-cause removal takes into account the illegal harvest. Between 1969 and 1977 an average of 180 illegal kills was reported annually. However, a study by Vilkitis (1971) indicated that the reported losses constituted only about 1.2% of the actual illegal harvest, which was probably closer to 15,000 to 18,000 annually.

The black bear kill for the townships in the characterization area is also summarized in table 17-5, for the years 1969 to 1977. No bears were killed in either region 1 or 3, and only one bear was killed in region 2. The highest bear kill was in region 5, where an average of 3 bears/100 sq mi were taken.

Harvest data for the other game species (except woodchuck and cottontail) are estimated by MDIFW by surveying a sample of licensed hunters each year. The accuracy of these harvest estimates is questionable, since the sample size is very small and hunters tend to exaggerate. For example, Hunt (1975) suggests the estimated harvest of red fox could be as much as twice the actual kill. One test of the accuracy of the survey is the estimate of the deer kill, which can be verified through tagging procedures. The survey estimate is consistently high, sometimes as much as 50%. Until more accurate data are available the estimates have little use except for comparative purposes, since biases should be consistent from one part of the State to another.

Estimates of the harvest of furbearing mammals are derived from two sources. One is a trapper survey conducted by the MDIFW. The trapper survey, which is similar to the hunter survey, is subject to the same biases, except that the percentage of trappers sampled is much larger. Nearly all licensed trappers received a questionnaire and approximately 60% were filled out and returned. Again, the harvests seem to be overestimated. The second method of determining the trapping harvest is by a tagging procedure similar to that used for deer and bear. Each beaver, otter, fisher, fox, marten, coyote, bobcat, and raccoon legally killed must be tagged by a State game warden before it can be sold. Beaver and otter have been tagged for several years but tagging of the other species began only a few years ago. Tagging is not required for muskrat, mink, skunk, or weasel, so accurate information is not available for these species. The number of animals tagged in the characterization area is summarized in table 17-6. Determination of the extent to which these harvests approach the current supply must await more accurate estimates of population sizes.

Table 17-5. Average Annual Legal Harvest of White-tailed Deer (1959 to 1977) and Black Bear (1969 to 1977) for Each of the Six Regions in the Characterization Area[a,b]

Species	Region						Total
	1	2	3	4	5	6	
White-tailed deer							
Total harvest	89.0 (2)	919.0 (16)	609.0 (11)	094.0 (37)	1138.0 (20)	787.0 (14)	5636
Deer killed/sq.mi.	0.4	1.8	1.8	2.3	1.5	1.4	
Black bear							
Total harvest	0.0	<1.0	0.0	6.0 (18)	20.0 (59)	8.0 (24)	34
Bear killed/100 sq.mi.	0.0	-	0.0	0.6	2.7	1.3	

[a]Numbers in parentheses are percentages of total for all regions.
[b]From MDIFW Files, Orono, Maine.

Table 17-6. Annual Harvest (Number of Pelts Tagged) and Average Price per Pelt (1976 to 1977 average) of 7 Species of Furbearers in Coastal Maine[a].

Species	Region 1	2	3	4	5	6	Total	Average price ($)
Raccoon (1 yr.)	200	1331	596	878	448	303	3816	19
Beaver (6 yr. avg.)	19	123	83	162	333	350	1070	28
Fox (1 yr.)	62	236	36	229	255	68	886	55
Fisher (5 yr. avg.)	<1	105	48	98	2	<1	253	89
Bobcat (4 yr. avg.)	0	1	1	7	37	41	87	82
Otter (2 yr. avg.)	1	11	6	9	18	19	64	55
Coyote (1 yr.)	0	0	1	3	3	12	19	34

[a]Maine Department of Inland Fisheries and Wildlife, MIDAS Files, Augusta, ME.

Other forms of direct mortality caused by man include illegal harvest (poaching), crippling losses during the hunting season, traffic and train accidents, intentional nuisance removals, predation by dogs, and environmental contaminants. Unfortunately, information on some of these losses is only available for deer and moose.

A 9-year summary of death due to factors other than hunting is presented in table 17-7 for deer and table 17-8 for moose. An average of 1917 deer were reported killed per year during this time (Lavigne 1978b). Most (64%) losses were due to accidents with cars and trucks, followed by dog kills (10%), illegal kills (9%), and unknown (4%) and miscellaneous (3%) causes. On a WMU basis total losses were correlated with the density of deer populations, and losses due to roadkills were correlated with the amount of rural roads/100 sq mi of deer habitat. For moose, total losses due to illegal hunting were most important (42%), followed by cars and trucks (34%), miscellaneous causes (9%), unknown losses (8%), and trains (6%) (Lavigne 1978a).

Table 17-7. Number of Deer Killed by Causes Other than Legal Hunting in Maine, 1969 to 1977[a].

Year	Cars or trucks	Illegal	Dog	Misc. or unknown	Wild predators	Crop protection	Trains	Total
1969	1109	100	241	229	42	37	19	1777
1970	1275	198	145	186	28	64	--	1896
1971	976	145	487	237	36	28	--	1909
1972	1281	209	131	124	63	28	23	1859
1973	1216	226	202	119	50	41	10	1882
1974	1322	265	53	72	26	30	9	1780
1975	1479	269	98	115	44	33	9	2047
1976	1160	154	131	118	55	23	7	1648
1977	1604	276	316	129	68	48	18	2459
Mean	1279	217	200	148	56	37	15	1917

[a]Lavigne 1978b.

Table 17-8. Number of Moose Killed by Causes Other than Legal Hunting in Maine, 1969 to 1977[a].

Year	Illegal kill	Car or truck	Misc. or unknown	Train	Predator	Total
1969	71	62	31	19	1	184
1970	96	65	45	10	0	216
1971	95	57	41	12	0	205
1972	70	60	50	13	0	193
1973	139	84	27	20	0	270
1974	121	90	41	19	0	271
1975	115	94	33	6	1	249
1976	110	95	38	8	0	251
1977	93	130	58	15	1	297
Mean	102	82	41	14	<1	237

[a]Lavigne 1978a.

Environmental contaminants. Humans also affect mammals by applying chemical pesticides to control agricultural and forest insect pests. Some of the chemicals sprayed on agricultural lands in the characterization area include Guthion, Diazinon, Benlate, Ferbam, Thrithion, Sevin, Systox, Disyston, Dithane, Monitor, Bladex, and Lasso. Chemicals sprayed for control of forest insect pests (primarily spruce budworm) include Sevin, Orthene, and Dylox, as well as experimental sprayings of Matacil and Lannate. Bacillus thuringiensis, a biological control bacteria, is also used. The persistent pesticides, such as DDT, have not been used since the early 1970s. The extent of pesticide use in the coastal zone and known impacts are discussed in chapter 3, "Human Impacts on the Ecosystem." The effects on mammals of the chemicals currently used seem to be minor. They break down rapidly (within a few days or weeks) and are not concentrated in animal tissues. Populations of nontarget insects may be reduced temporarily but this has not seemed to affect small mammal populations and no acute toxic effects have been noted (Conner 1960; Barrett 1968; Buckner et al. 1973, 1974, and1975; Caslick and Smith 1973; Buckner and Sarrazin 1975; and Stehn and Stone 1975).

Residues of DDT and its metabolites may still be present in some species of terrestrial mammals, as Dimond and Sherburne (1969) reported residues of DDT in shrews 9 years after application. The pattern of accumulation in mammal species was based on the food habits, as expected. Voles and mice (mainly herbivores) had low levels and were approaching pretreatment levels after 9 years. Shrews had 10 to 40 times as much as mice and voles and were still well above pre-spray levels after 9 years. The highest levels, 41 ppm, were high enough to cause acute mortality, which could result in local extinctions. Sherburne and Dimond (1969) also examined residues in snowshoe hares and mink. Hares had low levels which did not differ from hares on untreated areas. Mink had levels 10 to 90 times those found in hares and levels were still above pretreatment concentrations after 7 to 9 years.

IMPORTANCE TO HUMANITY

Mammals are valuable for recreational, economic, aesthetic, and scientific reasons. The most obvious values are those associated with recreation, i.e. hunting and trapping. There were over 218,000 licensed hunters in Maine in 1977, of which about 30,000 were nonresidents. While some of these may have been interested only in hunting game birds, it is estimated that over 80% of those holding hunting licenses hunted deer. The recreational importance of seven of the ten game species hunted for sport (no data for cottontail, woodchuck, or coyote) is indicated by the number of man-days effort expended in pursuit of these species (table 17-9). Deer provide the greatest amount of recreational value, with approximately 580,000 man-days of effort expended in Wildlife Management Units 6, 7, and 8. Following deer, in decreasing order of effort, are snowshoe hare (222,000), gray squirrel (38,000), black bear (32,000), raccoon (27,000), fox (21,000), and bobcat (13,000). The three Wilflife Management Units along the coast provide a large share of the total recreational value in hunting in the State. This proportion is highest for gray squirrel (69% of total man-days for the State), followed by snowshoe hare (57%), raccoon (51%), fox (46%), deer (45%), bobcat (31%), and bear (16%).

Furbearing mammals also provide recreational opportunity. The number of trappers pursuing each species of furbearers in WMUs 6, 7, and 8 is shown in table 17-10. Also shown is the number of trap-days effort (number of traps x

Table 17-9. Average Number of Man-days of Hunting Expended on 7 Species of Game Mammals in Wildlife Management Units 6, 7, and 8 During 1971 to 1972 Through 1976 to 1977[a]

Species	Wildlife management unit			Total	% of State total
	6	7	8		
White-tailed deer	125,228	177,528	275,723	578,479	45
Snowshoe hare	32,123	63,015	126,874	222,012	57
Gray squirrel	2310	10,748	25,409	38,467	69
Bear	17,032	2890	12,427	32,349	16
Raccoon	3341	9821	13,498	26,660	51
Red fox	3998	7813	9435	21,246	46
Bobcat	4829	2255	6350	13,434	31

[a]Data from Anderson et al. 1975a and b.

the number of days set) spent in pursuit of each species. More tappers pursued raccoon (406) than any other species, followed in decreasing order by fox (364), muskrat (329), fisher (311), beaver (292), mink (270), otter (114), skunk (83), weasel (55), bobcat (49), and coyote (27). In terms of trap-days effort, however, muskrat was highest (137,000 in the fall season, 99,000 in the spring season), followed by beaver (121,000), fox (75,000), raccoon (59,000), otter (17,000), skunk (11,000), bobcat (9000), weasel (8000), and coyote (3000). The importance of the coastal units in providing trapping recreation is indicated by the proportion of the total trap-days expended on each species within the coastal units. This ranges from 50% for muskrat to only 12% for coyote (table 17-10).

Mammals have economic values but cause economic losses also. The economic values associated with hunting and trapping include the money spent for license fees, firearms and ammunition, traps, guides, gasoline, food, and lodging. Also, trappers realize a direct return from furs sold on the market. As an indication of the importance of furbearers in the coastal regions, table 17-6 summarizes the number of furs tagged for each of seven furbearing species in the six coastal regions and the average price per pelt paid during 1976 to 1977. While this table does not include those species that need not be tagged (muskrat, mink, skunk, weasel), the value for just these species was over $180,000.

Table 17-10. Average Number of Man-days of Trapping for 11 Species of Furbearing Mammals for Wildlife Management Units 6, 7, and 8 During the Period 1973-1974 through 1976-1977[a,b]

Species	Wildlife management unit			Total	% of State total
	6	7	8		
Muskrat	35,695 (58)[c]	49,963 (98)	150,475 (173)	236,133 (329)	50
Beaver	50,503 (83)	29,307 (82)	41,335 (127)	121,145 (292)	29
Red fox	20,863 (76)	22,931 (112)	31,222 (176)	75,016 (364)	36
Fisher	277 (6)	33,236 (144)	26,946 (161)	60,459 (311)	47
Raccoon	15,776 (94)	20,387 (122)	23,441 (190)	59,604 (406)	35
Mink	16,138 (60)	14,319 (71)	13,351 (139)	43,808 (270)	30
Otter	9107 (33)	3843 (40)	3979 (41)	16,929 (114)	32
Skunk	3206 (14)	1043 (22)	6293 (47)	10,542 (83)	43
Bobcat	7849 (33)	346 (5)	1293 (11)	9488 (49)	27
Weasel	1101 (9)	3679 (11)	2776 (35)	7556 (55)	42
Coyote	843 (6)	450 (11)	1798 (10)	3091 (27)	12

[a]Numbers of trappers are given in parenthesis.
[b]Data from Anderson et al. 1975 c and d.
[c]Number of muskrat trappers taken as maximum of spring or fall season, whichever was larger.

Mammals sometimes destroy crops and livestock. Between 1946 and 1960 an average of $7600 was paid by MDIFW and landowners for damage caused by bears. This ranged from $2600 to $15,000 (Hugie and Banasiak 1975). There are no data on the costs associated with deer depredations but between 1969 and 1977, an average of 37 deer were killed each year as a result of complaints of crop damage (table 17-7). Other species of mammals that cause problems include beavers, bats, rats, mice, squirrels, and raccoons. Mammals are also important aesthetically, although quantifying aesthetic values is difficult. Most people enjoy watching mammals and the opportunity to view some of the more elusive mammals (such as mink, fisher, marten, and black bear) is an added reward to any outdoor activity. Acutal excursions to view mammals are probably limited to moose, deer, or beavers. Dunn and his colleagues (1975) identified 57 frequently used sites for watching moose in Maine. Only two are in the coastal WMUs, both in Unit 6, in Centerville and Northfield. While many people make day trips to view moose, it is doubtful that anyone comes to Maine specifically for that reason.

Finally, mammals are of concern to humanity as a source of diseases, the most obvious of these being rabies virus. The incidence of rabies among mammals in Maine averaged 73 cases per year during 1971 to 1977. The seven counties along the coast averaged 24 cases per year (32% of the State total; table 17-11). Of the wild mammals affected, foxes account for 64% of the positive cases. Most other species of wild mammals have relatively low incidences of rabies (table 17-12). Not only people but domestic animals also are susceptible to rabies. Domestic animals most affected are (in decreasing order) cattle, cats, dogs, sheep, goats, horses, and pigs (table 17-12). Since animals suspected of having rabies must be destroyed, the economic loss may be considerable.

MANAGEMENT

Management of terrestrial mammals is the responsibility of the Maine Department of Inland Fisheries and Wildlife. Management strategies for game and furbearing mammals are determined by assessing the present status of, and alternative goals and objectives for, each species. This information is compiled in species management plans, which then form the basis for management decisions. Periodically, these plans are updated and revised as necessary.

More important are management alternatives that can be employed by persons involved in making land-use decisions. As stated earlier, the most important influence man has on mammals concerns habitat quality and quantity. Persons proposing activities that will alter natural habitats should consider (1) the species of mammals using the habitats (figure 17-2), (2) the amount of that habitat type available (i.e., is it in short supply; see table 17-2 and appendix tables 1 to 9), and (3) whether that habitat is necessary for any species (figure 17-2). Increased awareness of particularly unique or rare habitats can be achieved by registering them with the Critical Areas Program of the Maine State Planning Office.

More specifically, logging effects can be mitigated by leaving deer wintering areas uncut; cutting in patterns that create a mosaic of successional stages in close proximity to one another (i.e., prevent large tracts of uniform habitat); using selective or partial cutting practices to preserve mature forest habitats; leaving large undesirable "cull" trees for den sites;

limiting planting and herbicide treatment to sites that are most productive for timber production; and leaving less productive sites to follow natural succession.

In agricultural areas large fields with a minimum of edge should be avoided; hedgerows and natural vegetation in corners and damp spots should be encouraged; and some crops should be left unharvested (i.e., corn or alfalfa) as food. Effective means of biological control should be used to minimize spraying of pesticides.

The opportunity for managing mammals is perhaps greatest in developed areas. Leedy and his colleagues (1978) have written an excellent guide to wildlife management in urban and suburban areas. They stress the importance of considering wildlife in the planning stages but also give management recommendations for existing developed habitats. These include: attempt to maintain entire ecosystems; use native plants for ornamental plantings; allow as many trees as possible, both alive and dead; provide multilayered habitats as opposed to monocultures; use natural drainage systems; avoid filling and dredging wetlands; provide continuous lanes of vegetation between parks; plan roads to minimize habitat loss; convert vacant lots to small parks or refuges; provide a diversity of plant species; consider biological control over pesticides; and, above all, retain natural habitat whenever possible.

Table 17-11. Incidence of Rabies in Coastal Counties, Listed West to East, of Maine from 1971 through 1977

County	Number of cases		
	Minimum	Maximum	Average
Cumberland	0	23	5
Sagadahoc	0	10	4
Lincoln	0	16	5
Knox	0	10	3
Waldo	0	20	6
Hancock	0	5	1
Washington	0	4	1

Table 17-12. Incidence of Rabies in Wild and Domestic Mammals in Maine from 1971 through 1978

Species	Average number of confirmed cases	Average number of suspected cases
Wild mammals		
Red fox	49 (2-93)	67
Bat spp.	2 (1-4)	46
Skunk	1 (0-6)	7
Raccoon	1 (0-8)	39
Deer	<1 (0-2)	2
Fisher	<1 (0-1)	1
Coyote	<1 (0-1)	0
Other (mainly rodents)	<1 (0-2)	57
Domestic mammals		
Cattle	7 (1-30)	33
Cat	4 (0-21)	95
Dog	3 (1-10)	49
Sheep	2 (0-13)	6
Horse	1 (0-4)	4
Goat	1 (0-3)	4
Pig	1 (0-3)	4
Total	73	414

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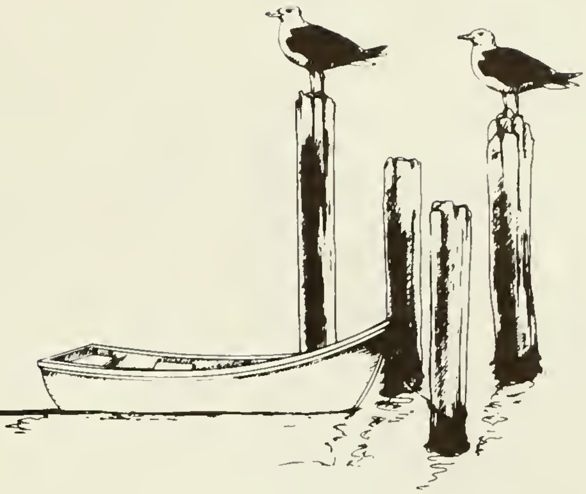

Chapter 18 Reptiles and Amphibians

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Resident reptiles and amphibians (collectively called herptiles) are not abundant in coastal Maine when compared to other eastern United States coastal areas probably because of the low winter temperatures and/or the short cool summers. However, certain habitats, such as marshes, bogs, and rivers, may support high numbers of some species. Sixteen amphibian species inhabit coastal Maine: eight salamander species, one toad species, and seven frog species. Fourteen resident reptile species are represented: five turtle species and nine snake species (table 18-1). In addition, there is one species of sea turtle, the leatherback (an endangered species), that is found regularly in low numbers in the marine system of coastal Maine. There are no native lizards in Maine.

Amphibians are poikilothermic (cold blooded) vertebrates with moist skins, and lungs or gills, through which they respire. They inhabit damp terrestrial habitats and freshwater aquatic environments. Several salamanders are primarily terrestrial but require moist microhabitats, e.g., under logs or in wet leaf-litter. Adult toads, although terrestrial, breed in aquatic habitats. All amphibian species have an amphibious larval stage.

Reptiles have dry, scaly skins, which help prevent desiccation, and respire through lungs. Snakes inhabit terrestrial systems mostly, while turtles are found primarily in or near freshwater systems. Reptiles have no larval stages.

Reptiles and amphibians are important to humanity scientifically and aesthetically. It has been suggested that amphibians could serve as indicators of environmental contamination, because their moist skins may concentrate toxic substances trapped during respiration (Porter 1972). Neither group has economic value in Maine, although bullfrogs and snapping turtles are used locally as food. High concentrations of snapping turtles can be a problem if they prey on young waterfowl and fish.

Table 18-1. Habitats[a] and Distribution of Herptiles in Coastal Maine

Species	Habitat or system	Region
Salamanders		
Blue-spotted salamander	LPT	all
Spotted salamander	LPT	all
Red-spotted newt	LPT	all
Northern dusky salamander	RP	all
Red-backed salamander	PT	all
Four-toed salamander	PT	4
Spring salamander	R	1
Northern two-lined salamanader	R	all
Frogs and toads		
American toad	LPT	all
Spring peeper	LP	all
Gray tree frog	LP	all
Bullfrog	RLP	all
Green frog	RLP	all
Northern leopard frog	RLP	all
Pickerel frog	RLP	all
Mink frog	LP	6
Wood frog	PT	all
Turtles		
Snapping turtle	RLP	all
Stinkpot	RL	1-4
Spotted turtle	LP	1
Wood turtle	PT	all
Eastern painted turtle	RLP	all
Sea turtle		
Leatherback	M	all
Snakes		
Northern water snake	RLP	6
Northern brown snake	T	all
Red-bellied snake	T	all
Eastern garter snake	T	all
Northern ringneck snake	T	all
Northern black racer	T	all
Smooth green snake	T	all
Eastern milk snake	T	all

[a]Includes breeding habitats.
[b]R=Riverine; L=Lacustrine; P=Palustrine; T=Terrestrial ; M=Marine.

This chapter describes the status of reptile and amphibian species along the coast of Maine; their species associations, food requirements, and reproductive biology; the factors that affect their distribution and abundance; and their importance to humanity. Data gaps and research priorities are indicated and current management practices applicable to herptiles are discussed.

DISTRIBUTION AND ABUNDANCE

Most species of amphibians and reptiles are found throughout the six coastal regions in the habitats listed in table 18-1. Exceptions are the spring salamander and the spotted turtle, which reach the northernmost extent of their ranges in the area of regions 1 or 2 (Pope 1915; and Babcock 1919). The abundance of herptile species in coastal Maine is not known. The eastern region, particularly the coastal area, has not been surveyed comprehensively. The limited distributions indicated in table 18-1 for the four-toed salamander, mink frog, stinkpot turtle, and northern water snake probably result from lack of adequate information. Information from northern Maine and other States indicates that reptiles and amphibians may be abundant, although inconspicuous. For example, a deciduous forest in New Hampshire supported approximately 3000 salamanders per hectare, with a biomass of 1770g/ha (wet weight; Burton and Likens 1975). This biomass is approximately twice that of breeding birds, and nearly equal to that of small mammals. These densities are comparable to those found elsewhere (Michigan, Pennsylvania, and Virginia). In northern Maine, populations of the red-backed salamander averaged 1100/ha in mixed hardwood-spruce fir forests (Banasiak 1974). More studies are needed to determine populations of these and other herptiles in coastal Maine. The importance of herptiles in the functioning of ecosystems probably has been underestimated (Burton and Likens 1975).

The leatherback turtle is an endangered species. The distribution of the leatherback turtle, as well as other species of sea turtles, is currently being investigated along the Atlantic coast from Cape Hatteras, North Carolina, to Nova Scotia (Shoop et al. 1979). During the first year of observation (1979) four leatherbacks were sighted in marine waters off the Maine coast. Leatherbacks appear rather suddenly along the Maine coast in late spring, and it is thought they move northward using the Gulf Stream for transport. Unlike other species of sea turtles, leatherbacks are capable of regulating their body temperture at about 80° F (27° C), and are thus able to survive in the cold marine waters along the Maine coast.

HABITAT PREFERENCES

The preferred habitats of many species of reptiles and amphibians differ according to the stages of their annual cycle. Many species that spend much of the year in terrestrial habitats move to aquatic habitats for breeding and egg laying. In addition, all reptiles and amphibians indigenous to the coastal zone must hibernate during the winter. Many species (e.g., terrestrial amphibians) hibernate in the mud on the bottoms of lakes and ponds. Others (i.e., aquatic amphibians) burrow in the ground. Snakes hibernate under rocks, tree roots, or underground. Snake dens are usually occupied by a number of individuals.

Among the salamanders found in coastal Maine, five are primarily terrestrial (table 18-2). These are the spotted, blue-spotted, red-backed, four-toed, and dusky salamanders (the red-backed is entirely terrestrial). Except during the breeding season these species are found in damp leaf-litter and under rocks and logs in moist woodland habitats. The four-toed salamander prefers swampy woods or peat bogs (Bleakney 1953). Two species, the spring and two-lined salamanders, are entirely aquatic. They remain in fast-moving riverine habitats throughout the year.

The red-spotted newt has three stages: one terrestrial and two aquatic. The red-spotted newt is found in moist woodland environments during the eft (between larvae and adult) stage. When the time comes for their transformation from eft to the adult stage, the efts migrate to emergent wetlands and shallow waters of ponds and lakes, the preferred habitats of the adult newt.

The American toad, the gray tree frog, and the wood frog are primarily terrestrial species that return to the water to breed (table 18-2). The true frogs (genus Rana) include species that range from almost totally aquatic (e.g., bullfrog and green frog) to almost entirely terrestrial (e.g., wood frog). The leopard frog is in the middle of this range, preferring grassy meadows and marshes.

Turtles found in the coastal zone are aquatic animals, occupying a variety of lacustrine, riverine, and palustrine habitats throughout the year. The one exception to this rule is the wood turtle, which is a terrestrial species. The snapping and stinkpot turtles prefer sluggish streams. The leatherback turtle prefers deep water marine habitats.

Snakes are found in a variety of terrestrial habitats, including forests, old fields, and agricultural land. The water snake is a semiaquatic species and is found usually in or near water.

BREEDING HABITS

The breeding seasons of amphibian species differ considerably. Most breed in spring or early summer but a few (such as the bullfrog and spring salamander) breed in late summer or early fall (table 18-2). In spring, blue-spotted and spotted salamanders seek the shallow waters of small ponds and lakes or small temporary bodies of water to begin breeding displays and egg laying. The four-toed salamander lays its eggs singly, dropping them into the water (Oliver and Bailey 1939). The red-backed salamander completes its breeding cycle within moist woodland habitat, where it deposits its eggs under rocks or rotten logs. The dusky salamander lays its eggs on land and the larvae may develop on land or migrate to nearby water, where development continues. The more aquatic species (spring and two-lined salamanders) lay their eggs under rocks and stones in fast-moving riverine habitats. The red-spotted newt is unique among the salamanders found in coastal Maine because it is aquatic in both the adult and larval stages. The eft stage is terrestrial and lasts from 1 to 3 years (usually 2).

Upon hatching from the egg most salamanders undergo a gilled larval development period, the length of which varies among species. An exception is the red-backed salamander, which hatches from the egg as a miniature adult.

Table 18-2. Herptile Breeding Seasons and Habitats

Species	J	F	M	A	M	J	J	A	S	O	N	D
Amphibians												
Blue-spotted salamander	-	-	-	P[a]	P	T	T	T	T	-	-	-
Spotted salamander	-	-	-	P	P	T	T	T	T	-	-	-
Red-spotted newt	-	-	-	P	P	P	P	P	P	-	-	-
Dusky salamander	-	-	-	T	T	R	R	T	T	-	-	-
Red-backed salamander	-	-	-	T	T	T	T	T	T	-	-	-
Four-toed salamander	-	-	-	P	P	P	P	P	P	-	-	-
Spring salamander	-	-	-	R	R	R	R	R	R	-	-	-
Two-lined salamander	-	-	-	R	R	R	R	R	R	-	-	-
American toad	-	-	-	P	P	P	T	T	T	-	-	-
Spring peeper	-	-	-	P	P	P	P	P	P	-	-	-
Gray tree frog	-	-	-	T	P	P	T	T	T	-	-	-
Green frog	-	-	-	P	P	P	P	P	P	-	-	-
Bullfrog	-	-	-	PR	PR	PR	PR	PR	PR	-	-	-
Leopard frog	-	-	-	P	P	P	P	P	P	-	-	-
Pickerel frog	-	-	-	P	P	P	P	P	P	-	-	-
Mink frog	-	-	-	P	P	P	P	P	P	-	-	-
Wood frog	-	-	-	P	P	T	T	T	T	-	-	-
Reptiles												
Snapping turtle	-	-	-	PR	PR	PR	PR	PR	PR	-	-	-
Stinkpot	-	-	-	PR	PR	PR	PR	PR	PR	-	-	-
Spotted turtle	-	-	-	P	P	P	P	P	P	-	-	-
Wood turtle	-	-	-	T	T	T	T	T	T	-	-	-
Painted turtle	-	-	-	P	P	P	P	P	P	-	-	-
Water snake	-	-	-	P	P	P	P	P	P	-	-	-
Brown snake	-	-	-	T	T	T	T	T	T	-	-	-
Red-bellied snake	-	-	-	T	T	T	T	T	T	-	-	-
Garter snake	-	-	-	T	T	T	T	T	T	-	-	-
Ribbon snake	-	-	-	T	T	T	T	T	T	-	-	-
Ringneck snake	-	-	-	T	T	T	T	T	T	-	-	-
Black racer	-	-	-	T	T	T	T	T	T	-	-	-
Smooth green snake	-	-	-	T	T	T	T	T	T	-	-	-
Milk snake	-	-	-	T	T	T	T	T	T	-	-	-

[a]P=Palustrine; R=Riverine; T=Terrestrial; -=Hibernation (varies with region).
Habitat symbols underlined indicate months of breeding.

Among the frogs and toads, the American toad, gray tree frog, and the wood frog are primarily terrestrial but migrate to a variety of palustrine habitats during the breeding season (spring and early summer) to lay their eggs in shallow water. The spring peeper and the remaining frog species found in coastal Maine occupy palustrine and riverine habitats throughout the year. Breeding takes place from June through July (personal communication from B. Burgason, Maine Department of Inland Fish and Wildlife, Bingham, ME; March, 1979). Among all species of toads and frogs the eggs hatch into a "tadpole," or larval stage. Tadpoles metamorphose into adults after periods of time that vary with species. Bullfrog tadpoles overwinter before metamorphosing into adults.

Turtles in coastal Maine breed in spring and summer. The females lay their eggs in cavities dug in sandy soil or in humus along river banks, shores of ponds, lakes, or palustrine wetlands. The eggs usually hatch by September. Turtles have no larval stages.

The snakes found along the coast of Maine fall into two reproductive categories: those that give birth to living young (water, brown, red-bellied, ribbon, and garter snakes) and those that lay eggs (ring-necked, green, black racer, and milk snakes). The living young are born in late summer, the eggs hatch usually in August or September (Oliver and Bailey 1939). Snakes have no larval stages.

FOOD HABITS

Reptiles and amphibians of coastal Maine are primarily carnivorous, feeding on a variety of animal life, principally invertebrates. The major exceptions are the turtles, which consume both plant and animal matter. Adult terrestrial salamanders eat terrestrial insects (adults and larvae), as well as other available invertebrate fauna, including spiders, mites, and various worms. Larvae of all terrestrial salamanders feed on insects. Aquatic larval salamanders prey on aquatic insect larvae, supplementing their diets with other available animal material.

Adult American toads, tree frogs (spring peeper and gray tree frog), and the more terrestrial frogs (pickerel, leopard, mink, and wood) eat insects primarily, and a wide variety of other invertebrates. The more aquatic frogs (green frog and bullfrog) eat aquatic insects principally, and other available invertebrate foods. The bullfrog also consumes some vertebrate prey, including small fish, and other herptiles (Oliver and Bailey 1939). The larvae of toads and frogs are herbivores and detrivores, feeding on algae and decomposing material from the surfaces of their aquatic environments.

Turtles in the coastal zone are generally omnivorous, eating a variety of invertebrates, a few vertebrates, and vegetable material. Snapping turtles occasionally may eat fish and become a nuisance in proximity to fish hatcheries and natural spawning areas. Under certain circumstances the snapping turtle may be a serious threat to fish fry and ducklings (Coulter 1957 and 1958). The leatherback turtle feeds primarily on jellyfish.

Snakes indigenous to the Maine coast are predators. The larger species (water, garter, ribbon, black racer, and milk) eat small vertebrates (mice, birds, and shrews) as well as insects and other invertebrates. The semiaquatic water snake preys upon small fish and frogs. The smaller snakes (brown, red-bellied, ring-necked, and smooth green) eat insects, earthworms, slugs, and other invertebrates. The green snake eats adult and larval insects almost exclusively (Oliver and Bailey 1939).

FACTORS OF ABUNDANCE

Although natural factors largely determine the distribution and abundance of most animals, human-induced factors increasingly alter the ecosystem and their inhabitants. Some of the major factors that affect herptiles are discussed below.

Natural Factors

The relatively long, cold winters and short, cool summers of coastal Maine are probably the most influential natural limiting factor to reptiles and amphibians. Other natural factors affecting abundance of herptiles are forest and ground fires, beaver dams, predation, and the degree of abundance of food and cover. The extent to which these factors affect populations of amphibians and reptiles on the Maine coast is not known, but none appears to be particularly limiting.

Human Factors

Agriculture. Erosion from cultivated fields may damage herptile habitats seriously by causing siltation of nearby streams, rivers, and ponds (see "Agricultural and Developed Land," chapter 10 and "Human Impacts On the Ecosystem," chapter 3). However, farm ponds generally benefit most species of herptiles, especially frogs, and salamanders, through the creation of freshwater aquatic habitat. The fact that large acreages of blueberry barrens are routinely burned may affect populations of herptiles living in these habitats adversely, especially the blue-spotted, spotted, red-backed, and dusky salamanders, and several species of snakes, including the black racer, garter, and green snakes. The American toad, once abundant on Mount Desert Island (region 4) was virtually eliminated during the massive fire of 1947 that swept the island (Davis 1959).

Pollution. The introduction of toxic chemicals and sediments from soil erosion into coastal Maine could play major roles in reducing the abundance of herptiles (Porter 1972). An average of 10,000 to 12,000 lb (4500 to 5500 kg) of Guthion was sprayed on blueberry fields in Washington County between 1971 and 1976 (Maine Soil and Water Conservation Commission 1978). Air pollution and acid rain could have an adverse effect on populations of terrestrial salamanders, which respire through their skins.

Bart and Hunter (1978) have compiled an annotated bibliography on the biological impact of selected insecticides on vertebrates and invertebrates. According to these authors no significant impact on populations of herptiles was noted in experiments with various dilutions of the insecticides commonly used in Maine (e.g., Zectran, Dylox, and Guthion) against spruce budworm or on agricultural crops, but populations of aquatic insects (e.g., mayflies, stoneflies, and various fly larvae) were reduced by some of these chemicals. Certain insects used by aquatic herptiles as food were among these. In addition, pesticide and oil films on pond surfaces may interfere with the dermal oxygen exchange of transforming amphibians (Porter 1972). Insects dying from pesticides often go into convulsions, and adult toads and frogs may orient towards these struggling insects (Sassamon 1978). Frogs and toads were found to have concentrations of 6 to 222 ppb Orthene (Acephate) immediately following a spray to kill spruce budworm, but after 30 days there were no detectable residues (Sassamon 1978).

Impoundments. Small artificial dams have created new ponds and wetlands in coastal Maine. Cook (1967) discovered that many salamander and frog species had increased in abundance on Prince Edward Island, Canada, because of these dams. Millponds used by the logging industry have formed new habitat for several species, principally the red-spotted newt, green and leopard frogs, and the American toad. The adverse effects such structures would have on species such as the dusky and two-lined salamanders, which prefer small, flowing streams have not been investigated. Similar structures in coastal Maine may provide additional habitat for aquatic herptiles.

Land, water, and forest disturbances. Many small gravel extraction operations are present in coastal Maine, especially in region 6. When gravel eskers are mined near bodies of water the quality of herptile habitat may be reduced through erosion and siltation.

Peat mining, conducted principally in Washington County (region 6), probably does not reduce significantly the preferred habitat (sphagnum bog) of most herptile species, with the possible exception of the four-toed salamander. However, increased siltation due to peat mining could reduce water quality.

Rights-of-way maintained along highways and beneath power lines or pipelines may provide brushy habitat for species such as the black racer (personal communication from D. F. Mairs, Pesticide Control Board, Augusta, ME; February, 1979). Transmission corridors may alter the abundance of herptiles locally, by changing drainage patterns in adjacent areas, and thereby creating small, temporary palustrine areas that may serve as breeding areas for herptiles (blue-spotted and spotted salamanders and most frogs).

Forest cutting practices have great potential for altering habitats. Clearcut or strip harvesting methods expose areas of the forest floor that have been shaded previously, causing them to dry out. Such activities destroy preferred habitat of many terrestrial salamanders and the wood frog. Subsequent brushy growth in these clearings provides new habitat for black racer and garter snakes. As a result of these logging practices adjacent bodies of water may be subject to silting and lowering of pH. These processes could reduce the abundance of herptiles (Porter 1972).

Road construction adjacent to breeding areas increases the hazard of roadkills for some herptile species, especially those that move in large numbers to breeding ponds (blue-spotted and spotted salamanders, the American toad, and all frog species and turtles). Brush removal and landscaping in suburban areas can have an adverse effect on many herps because they depend on brush and fallen logs for their shelter and habitat.

IMPORTANCE TO HUMANITY

People use small numbers of bullfrogs and snapping turtles as food. Some smaller species of frogs (pickerel, leopard, and green) are used as fish bait.

Amphibians could serve as indicators of environmental contamination. Their moist skins may hold concentrations of toxic chemicals and other environmental pollutants trapped during respiration (Porter 1972). No data are available on this subject, however.

MANAGEMENT

The integrity of freshwater aquatic and terrestrial habitats important to reptiles and amphibians needs to be maintained in coastal Maine. No laws exist at present governing the collecting or possession of herptiles in the State of Maine (personal communication from B. Burgason, Maine Department of Inland Fisheries and Wildlife, Bingham, ME; March, 1979). Such laws may be necessary for the preservation of these animals if the magnitude of collecting increases.

RESEARCH NEEDS

Very little information is available on reptiles and amphibians along the coast of Maine. The only available distributional information that is specific to coastal Maine is local. Some data on food habits of the snapping turtle (Coulter 1957, 1958, and 1968) are available.

Population studies of herptiles in coastal Maine are needed to provide information on the role of herptiles within ecosystems. Information is needed on the impact of pesticides on herptiles. Further research is needed to determine if sphagnum-peat bogs are the preferred habitat of the four-toed salamander, as suggested by Bleakney (1953) and Burgason and Davis (1978). If so, the effects of peat mining on this rare species will need to be determined. Studies also need to be conducted to determine the effects of regular burning of blueberry barrens on the abundance of reptiles and amphibians.

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Chapter 19 Commercially Important Forest Types

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Trees occur in abundance on virtually all of the terrestrial habitats in the characterization area. They are present on all types of terrestrial habitat, from open pine barrens to urban centers and provide suitable habitat for many plant and animal communities. Due to diverse habitat and reproductive requirements, trees of the coastal zones, (a term that will be used synonymously with "characterization area" here) evolved unique adaptive mechanisms to help guarantee their survival (e.g., closed cones in jack pine that open and disperse seeds after fire).

Trees have direct economic importance to people. Collectively, the 43 tree species (table 19-1) found in the region are its most important commercial plant crop (see also chapter 9, "The Forest System"). Examples of wood-product industries supplied with raw materials from the coastal zone include: pulp and paper, lumber, veneer, turnings (including lobster traps, pallet stock, and box boards), slack cooperage, fencing, shingles, Christmas trees, wreaths and greens, spruce gum, salad bowls, paddles, bowling pins, log cabins, maple syrup and firewood (Ferguson and Kingsley 1972).

People have influenced the number and diversity of tree species in the coastal zone by altering habitat conditions (through agriculture, construction, logging, soil moisture drainage, and fire among others) and by harvesting some species (e.g., eastern white pine, red spruce, and paper birch) in greater quantity than others.

This chapter is designed to familiarize the reader with the commercial forests and common tree species of the coastal zone and to discuss current forestry practices within this region. Emphasis is placed on the impacts (silvicultural and environmental) of these practices. The term forest type as used here is "a descriptive term used to group stands of trees of similar character in regards to composition and development due to certain ecological factors, by which they may be differentiated from other groups of stands" (Society of American Foresters 1964).

Table 19-1. Common Commercial Tree Species of the Characterization Area[a,b]

Common name	Taxonomic name
Atlantic white-cedar	Chamaecyparis thyoides (L.) B.S.P.
Eastern red cedar	Juniperus virginiana L.
Tamarack	Larix laricina (DuRoi) K. Kock
Norway spruce (exotic)	Picea abies (L.) Karst
White spruce	P. glauea (Moench) Voss
Black spruce	P. mariana (Mill.) B.S.P.
Red spruce	P. rubens Sarg.
Jack pine	Pinus banksiana Lamb.
Red pine	P. resinosa Ait.
Pitch pine	P. rigida Mill.
Eastern white pine	P. strobus (L.)
Scotch pine (exotic)	P. sylvestris (L.)
Douglas fir	Pseudotsuga menziesii (Mirb.) Franco
Northern white cedar	Thuja occidentalis L.
Eastern hemlock	Tsuga canadensis L.
Balsam fir	Abies balsamea (L.) Mill.
Red maple	Acer rubrum L.
Silver maple	A. saccharinum L.
Sugar maple	A. saccharum Marsh.
Yellow birch	Betula alleghaniensis Britton
Sweet birch	B. lenta L.
Paper birch	B. papyrifera Marsh.
Gray birch	B. populifolia Marsh.
American hornbeam	Carpinus caroliniana Walt.
Shagbark hickory	Carya ovata (Mill.) K. Koch
American beech	Fagus grandifolia Ehrh.
White ash	Fraxinus americana L.
Black ash	F. nigra Marsh.
Green ash	F. pennsylvanica Marsh.
Butternut	Juglans cinerea L.
Eastern hophornbeam	Ostrya virginiana (Mill.) K. Koch
Balsam poplar	Populus balsamifera L.
Bigtooth aspen	P. grandidentata Michx
Quaking aspen	P. tremuloides Michx.
Black cherry	Prunus serotina Ehrh.
White oak	Quercus alba L.
Bar oak	Q. macrocarpa Michx.
Northern red oak	Q. rubra L.
Black oak	Q. velutina Lam.
American basswood	Tilia americana L.
American elm	Ulmus americana L.
Slippery elm	U. rubra Muhl

[a] Maine Forestry Department 1973.
[b] Names according to Little 1953.

The forest communities are divided into three main forest types: spruce-fir; maple-beech-birch; and white pine-hemlock-hardwood. Each forest type will be analyzed for habitat conditions, reproduction and growth, management methods, and occurrence of natural enemies. Analysis by this method readily facilitates discussion of ecological interactions. The grouping of forest types here necessitated the inclusion of several minor forest types recognized by the United States Forest Service as occurring in the coastal zone (table 19-2). Separate sections in the chapter are devoted to fuel wood production and Christmas tree production.

Biological and silvicultural knowledge of tree species in the characterization area is relatively widespread because the species are all common in Eastern North America and have been well studied in various parts of their botanical ranges. However, they have not been well studied in coastal areas and facts such as species' modifications and adaptations to the maritime climate are little known.

The information used to prepare this chapter has been compiled from research conducted by: universities in the Northeast (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York), the North Central States (Michigan, Wisconsin, and Minnesota), and Canada (Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland), the U.S. Forest Service, the Canadian Forest Service, and individual State and Provincial forest service organizations.

Precise statistical data (e.g., sawtimber volume, forest land area by ownership class, timber growth, and available cut projections) for the coastal zone are not available. However, the Forest Survey unit of the United States Forest Service inventoried the timber resources of Maine during 1968 to 1970 (Ferguson and Kingsley 1972), so some information on forest conditions and production (table 19-3 and figure 19-1) is available. See atlas map 2 for types of land cover found in the characterization area. Geographic sampling units in Maine, as presented by Ferguson and Kingsley (1972), are shown in figure 19-1. The Casco Bay Unit, the Capitol Unit, and the Hancock and Washington Units encompass most of the characterization area. Units are delineated on the basis of homogeneity of tree species in so far as possible. Common names of species are used except where accepted scientific names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

The 1968 to 1970 Forest Survey points out the following general trends in Maine's timber resource that deserve attention:

1. Softwood (one of the botanical group of trees that have needle or scale-like leaves) growing-stock is increasing at a much greater rate than that of hardwood (one of the botanical group of trees that have broad leaves).
2. About two-thirds of the sawtimber volume is in trees <15.0 inches, or 38 cm, diameter at breast height (dbh; 4.5 feet, or 1.4 m, above average ground level).
3. Although growth exceeds removal for total growing-stock, the growth-to-removal ratios of northern white cedar, northern red oak, white ash, yellow birch, white pine, sugar maple, and beech show overcutting.

4. Projections of future timber supply show that, if present removal trends continue, hardwood removals will exceed growth within a few years, and softwood removals will exceed growth before the turn of the century.

These observations illustrate an increased effort must be made to encourage landowners to practice good forest management. These efforts must be directed to hardwoods, particularly if growth is to keep pace with demand.

SPRUCE-FIR TYPE

Habitat Conditions

Red spruce, white spruce, and balsam fir are the predominant species in the spruce-fir type. Black spruce is also a minor component. Depending on site conditions, stands (aggregations of trees occupying a specific area and sufficiently uniform in composition, age arrangement, and condition as to be distinguishable from the forest on adjoining areas) may contain only spruce and fir or spruce-fir in various combinations with other conifers and hardwoods. Other conifers include northern white cedar, eastern hemlock, eastern white pine, and tamarack; and the hardwoods include red maple, paper birch, the aspens, white ash, American beech, sugar maple, and yellow birch (Hart 1964). Red spruce, white spruce, and balsam fir will grow on a variety of soils, including those that are poorly drained (McLintock 1954). The soils where spruce-fir grow are mostly acid podzol with a thick mor humus and well-defined A_2 horizon, characteristics commonly associated with abundant rainfall, cool climate, and coniferous cover. Black spruce is generally confined to bogs and muck soils.

The shade tolerance of spruce and fir and the multiple-aged condition of the stands in which they normally occur make the identification of "good" and "poor" growing areas difficult. Westveld (1941) devised a system whereby the areas can be classified either as primary softwood sites or secondary softwood sites. These classes are meaningful in terms of potential stand composition, growth, and reproduction.

Primary softwood sites usually occur in areas with poor or impeded drainages in the so-called spruce-fir swamps, flats, and other lower topographic positions. Spruce-fir also is common on the thin soils of upper slopes. Characteristic shallow rooting on these soils makes open stands susceptible to windthrow. These sites are composed mostly of softwood species. Hardwoods comprise less than 25% of the stands and are mostly paper birch, yellow birch, aspen, red maple, and an occasional beech or sugar maple.

Secondary softwood sites occur on the better-drained areas of higher topographic elevation and on medium-elevation ridge lands. Hardwoods may comprise from 25% to as much as 70% of the stands on these sites, often competing sharply with spruce-fir. The tolerant red spruce and balsam fir may become established in the understory, responding to release if the overstory is removed. On such sites, the hardwoods usually are beech, sugar maple, and yellow birch. Herbaceous vegetation is less common than shrubs such as witch hobble, striped maple, and mountain maple.

Table 19-2. Forest Types of the Characterization Area[a]

Forest type	Description
Spruce-Fir	Forests in which balsam fir or spruce (black, red, white), singly or in combination, make up a plurality of the stocking. Northern white-cedar swamps are also included. Common associates include tamarack, red maple, white birch, and eastern hemlock.
Maple-Beech-Birch	Forests in which sugar maple, American beech and yellow birch, singly or in combination, are the major components. Associated are various admixtures of basswood, red maple, northern red oak, white ash, eastern white pine, balsam fir, black cherry, paper birch, gray birch, American elm, slippery elm, eastern hophornbeam, red spruce, and white spruce.
White Pine-Hemlock-Hardwood	Forests in which eastern white pine and eastern hemlock are predominant. The hardwood associates are numerous but none are particularly characteristic. The principal ones are American beech, sugar maple, basswood, red maple, yellow birch, paper birch, white ash, and northern red oak.

[a]Adapted from Ferguson and Kingsley 1972 and modified to conform to Barrett 1962.

Table 19-3. Area (acres x 1000) of Commercial Forest Types of the Characterization Area[a]

Region[b]	Forest type		
	Spruce-fir	Maple-beech-birch[c]	White pine-hemlock-hardwood[d]
Capitol	336.2	447.9	348.1
Hancock	472.0	263.8	126.9
Washington	850.3	445.2	133.5
Totals	1658.5	1156.9	608.5

[a] Adapted from Ferguson and Kingsley 1972.
[b] Although Ferguson and Kingsley include a small amount of the characterization area in the Casco Bay and Penobscot Regions, it is so small that including it here would confuse interpretation of the data.
[c] Includes Aspen-birch and Elm-ash-red maple types recongnized by Ferguson and Kingsley 1972.
[d] Includes Oak and Oak-pine type recognized by Ferguson and Kingsley 1972.

Figure 19-1. Geographic sampling units in Maine (Ferguson and Kingsley 1972).

Reproduction and Early Growth

Red spruce produces good seed crops every 4 to 8 years, white spruce every 2 to 6 years, and balsam fir every 2 to 4 years (Fowells 1965). Seed production may begin when trees are about 15 years, but significant production usually does not begin until the trees are 25 to 30 years or older. Very few viable seeds are stored in the forest floor for more than one year. Some of the silvical characteristics of the major species are given in table 19-4. All three spruce species are tolerant of shade but require considerable light for rapid growth and development. In the coastal zone, white spruce develops pure stands on oldfield sites. These stands exhibit the same characteristics of growth and form that are expected in plantation-grown trees. All three species may form physiographic climaxes on poorly drained sites but on the better soils are subclimax to, and often mixed with, hardwoods such as sugar maple and beech (Westveld 1953).

Spruce-fir stands normally reproduce readily and have remarkable recuperative capacity (Barrett 1962). Advanced spruce-fir reproduction under many older stands may assure new spruce-fir stands after the overstory is harvested, unless fire occurs. Favorable seedling development is greatly affected by light, temperature, and moisture conditions. Initially, the light requirements conducive to early establishment seem not to exceed 10% of full sunlight (Vezina and Peck 1964). However as the seedling develops, light intensities of 50% or more are necessary for optimum growth (Shirley 1943). Soil surface temperatures between 115°F (46°C) and 130°F (54°C) result in the death of most young conifer seedlings even when they are exposed for very short periods of time (Baker 1929). Damage caused by late frost to leaders and new lateral growth is seldom severe.

Spruce seedlings are weaker and more fragile than fir and grow slower during the establishment phase (Fowells 1965). Seedlings that have obtained a height of 6 inches (15 cm) are considered to be established. Once a seedling becomes established, early growth is determined largely by the amount and character of overhead competition. Dense growth of bracken fern, raspberry, and hardwood sprouts are the chief competitors of seedlings on heavily cutover lands, but both fir and the spruces will survive many years of suppression and still respond to release. If left undisturbed, most stands of this type will contain a number of age classes because most species will survive under heavy shade; however, the main canopy of many stands is even-aged because they developed after depredation by insects, hurricanes, fire, and clear-cutting of mature stands around 1900 (Coolidge 1963).

Management Methods

The spruce-fir tree species in the characterization area are suited to management in either even-aged or uneven-aged stands (Frank and Bjorkbom 1973). Both types of management are commonly used although the exact acreages of each are unknown. Since the ecological interactions resulting from use of each type are so clearly different, a detailed description of each follows.

Table 19-4. Selected Silvical Characteristics of Important Commercial Tree Species of the Characterization Area[a]

	Shade tolerance[b]	Soil moisture[c]	Growth rate[d]	Longevity[e]	Natural reproduction[f]	Place in succession[g]
<u>Softwoods</u>						
Balsam fir	vt	m-w	r	s	ve	s
White spruce	vt	m	r	l	e-m	s
Black spruce	t	d-w	r	l	e	csp
Red spruce	vt	m-w	r	l	m-e	c
Eastern white pine	i	d-w	vr	l	d	s
Eastern hemlock	vt	d	r-m	l	d	s
<u>Hardwoods</u>						
Red maple	t	d-w	m	s	e	c
Sugar maple	t	m-d	r	m	e	c
Yellow birch	t	m	r	l	d	s
Paper birch	i	d	r	s	e	s
American beech	t	d-m	m	m	ve	s
White ash	m	m	m	m	e	s
Quaking aspen	vi	d	r	s	e	p
Northern red oak	i	d	r	m	vd	s
American elm	t-m	m	m	m-l	m	s

[a]Adapted from Society of American Foresters 1955.
[b]Shade tolerance: very intolerant (vi); intolerant (i); medium (m); tolerant (t); very tolerant (vt).
[c]Soil moisture: dry (d); medium (m); wet (w).
[d]Rate of growth: very rapid (vr); rapid (r); medium (m).
[e]Longevity: short (s); medium (m); long (l).
[f]Natural reproduction: very easy (ve); easy (e); medium (m); difficult (d); very difficult (vd).
[g]Place in succession: pioneer (p); subclimax (s); climax (c).

Uneven-aged stands are those in which the trees are of at least three distinct age classes irregularly mixed (Society of American Foresters 1964). Except for very old stands, uneven-aged stands are distinctly irregular in height and tree size. These stands are developed or maintained by relatively frequent harvests made throughout the rotation age (the number of years required to establish and grow timber crops to a specified condition of maturity). The distribution of diameter measurements in a balanced uneven-aged stand will plot into a characteristically inverted J-shaped curve.

Even-aged stands are those in which the difference between the oldest and the youngest trees does not exceed 10 to 20 years or 25% of the length of the rotation age. Trees in these stands tend to be uniform in height, but frequently they cover a wide range of diameter widths. These stands usually develop after the sudden removal of previous stands by logging, fire, insect epidemic, or other cause. A plotting of diameter widths will usually result in a normal curve.

Management of uneven-aged stands. In uneven-aged stands mature trees are removed as scattered individuals or in small groups at relatively short time intervals (10 to 15 years on primary softwood sites and 20 to 25 years on secondary softwood sites). The interval between cuts is based on growth rates, stand conditions, and size of the intended harvest. Individual trees or groups of trees are marked before cutting. The criteria used for marking trees for removal are: (1) poor-risk trees (those assumed to be doomed before the next harvest), (2) poor quality trees, (3) slow-growing trees, (4) trees of less desirable species, (5) trees whose removal will improve spacing in the residual stand, and (6) mature trees of good quality, good risk, desirable species, and fast growth. The term "selection system" is applied to any silvicultural program that is aimed at the creation or maintenance of uneven-aged stands and that includes some form of periodic harvesting. Because spruce and fir are usually able to reproduce and grow under overhead shade, uneven-aged stands will develop in areas not drastically disturbed by nature or people. Advantages of using the selection system of cutting in the spruce-fir type are:

1. Periodic harvests guarantee that a continuous forest cover is maintained.
2. The retention of spruce trees can favor the regeneration of this species with a corresponding reduction in fir.
3. Environmental conditions are stable so that plant and animal populations do not fluctuate much.
4. Fire hazard from slash accumulation (fallen branches and twigs) is not severe.
5. There is less chance of losing an entire stand at one time to insect attack, infectious disease, or other natural catastrophies.
6. The stands, except for the period immediately after a cut, appear attractive to the esthetic-conscious public.

Management of uneven-aged stands is complex. Because operations are conducted in mixtures of different age classes logging damage to, and death of, some uncut trees is difficult to prevent. Harvesting operations usually are difficult and expensive in that large land areas must be covered to obtain a given volume of wood.

The criteria for wise removal of trees are not adhered to in the coastal zone. Instead, a selection method known as diameter-limit harvesting is employed. Under this method all trees over a specified minimum diameter are removed. Diameter limits range from 8 to 15 inches (20 to 38 cm) for the spruces and over 6 inches (15 cm) for balsam fir. This method of cutting is conducive to future stand development and keeps the cost of harvesting reasonably low, however, diameter-limit harvesting removes large vigorous trees and leaves small, poor-risk and defective trees. In some areas too many trees per acre are removed, while too few are removed in other areas. The overall effect of the diameter-limit method is to lower the quality of the stand. The long-term genetic makeup of the forest is also affected adversely since only the best trees are removed with each cutting, and the poorer trees remain to disperse seeds and repopulate the area. Positive responses to selection for several traits have been shown for most tree species growing in the spruce-fir type (Wright 1976). Negative responses due to diameter-limit cutting practices are to be expected but no confirmed dysgenic effects (detrimental to the genetic quality) have been shown to date in the coastal zone. Diameter-limit cutting is also frequently applied to the northern hardwood and white pine-hemlock-hardwood types under the guise of selective harvesting.

Management of even-aged stands. Development of highly mechanized harvesting systems has prompted the use of even-aged stands in the management of the spruce-fir type. Although various methods of establishing even-aged forest stands have found application, the method most frequently used in the characterization area is the clearcutting method. In clearcutting, all trees on an area are removed in one cutting, with subsequent regeneration being obtained from seed disseminated by adjacent forest stands and/or by the trees being removed in the harvesting operation. Different methods of clearcutting are discussed in "White Pine-Hemlock-Hardwood Forest Type." Cutting areas may also be artificially regenerated by planting seedlings or sowing seed.

It is difficult to characterize all of the clearcutting operations that are presently taking place in or near the characterization area. A typical operation would have these component parts: (1) mature trees are cut either mechanically or by hand; (2) they are delimbed in the woods or are dragged to the roadside and then delimbed; (3) a reproduction survey is performed on the area and if adequate reproduction of desired species is expected to take place, no additional reforestation steps are taken; if an adequate reproduction is not expected, planting is done; (4) 2 to 3 years after clearcutting, the area is aerially sprayed with herbicide to kill hardwoods, raspberries, and other competing vegetative growth.

Major ecological implications of clearcutting are as follows:

1. The effect of mechanical harvesting on soil quality. Holman (1977) found that no permanent compaction of soils was present in clearcut areas as bulk densities returned to preharvest levels after one complete overwintering period. The most compaction observed was on skid trails that had been used in the summer. Several different types of mechanical harvesting systems are currently in use in the coastal zone, however, and different levels of compaction could be expected with different systems.

2. The effect of redistribution of logging slash (unwanted portions) and removal of all above-ground portions of trees on nutrient levels. Weetman and Webber (1972) found that full-tree logging will not cause any reduction in growth from nutrient removal during the second rotation of trees. However, nutrient depletion due to full-tree logging, particularly calcium, potassium, and nitrogen depletion, may require correction in forest ecosystems of marginal fertility. These sites are usually either dry, with low reserves of organic matter and low exchange capacity, or wet, with excessive accumulations of organic matter. No work with nutrient depletion has been done on logging areas in the characterization area.
3. The change in vegetation that occurs in an area is a result of increased light and decreased soil moisture. Bird and mammal populations are also affected when vegetation changes. See chapter 9, "The Forest System," for a discussion of these factors.
4. Soil erosion and siltation of streams are dependent upon soil types, slope, and the time of year the clearcutting operation is performed. Usually, clearcutting should not cause serious erosion of sites or siltation of streams if proper harvesting procedures are followed; however, no relevant data on the characterization area are available and it must be obtained if the extent of erosion and siltation due to clearcutting is to be measured.
5. The effects of spraying herbicides on the forest ecosystem are not completely understood (see chapter 3, "Human Impacts on the Ecosystem"). This topic is of national concern and has been the subject of heated debate in recent months. The Environmental Protection Agency (EPA) banned the use of 2,4,5-T (which had been used in coastal Maine) on forest lands in March, 1979.

Cubic foot yields per acre from fully stocked, even-aged stands of second-growth red spruce in the northeast are given in table 19-5. Because yield relationships between sites and for stands within sites are not distinct, there is an overlapping of various sites and stand types for specific yield values. The yield values in the table are given for four combinations of sites and stand types. These yields are from so called normal unmanaged stands. Yields from stands under a management scheme, including periodic harvests or thinnings, would be substantially higher over a rotation. No yield information on other species in even-aged stands is available.

Management practices, including silvicultural manipulation, have a strong influence on net annual growth. For example, experimental data have shown that well-managed stands on reasonably productive sites can produce nearly twice as much merchantable wood as unmanaged stands over the course of a rotation age (Frank and Bjorkbom 1973). Net annual growth during the first 10 years after selective cutting in primary softwood stands ranged from 47 to 82 cu ft/acre annually in several experiments in northern Maine (Frank and Bjorkbom 1973). Similar data for softwood sites in the characterization area are not available.

Table 19-5. Cubic-foot Yield/acre of Fully Stocked, Even-aged Stands of Second-growth Red Spruce in the Northeast by Stand Age, Site, and Stand Type[a,b]

Age (years)	Secondary softwood site (lower slopes, old farmland)	Primary softwood site (flats, old farmland):and secondary softwood site(lower slopes, old farmland)	Primary softwood site (swamps, flats, upper slopes, old farmland):and secondary softwood site(lower slopes)	Primary softwood site (swamps upper slopes)
	Cu ft	Cu ft	Cu ft	Cu ft
40	1650	1110	600	138
50	3770	2760	1670	480
60	5550	4200	2750	940
70	6620	5150	3470	1400
80	7280	5700	3920	1670
90	7650	6000	4160	1800
100	7870	6190	4310	1900

[a] Based on the merchantable cubic-foot volume in trees in the 4-inch and larger diameter classes from a 1-foot stump to a top of 3 inches inside bark.

[b] Frank and Bjorkbom 1973.

Natural Enemies

Although many insects and diseases damage spruce and fir, spruce is relatively free from these hazards until it matures. Fir, at all ages, is subject to insect and disease attack.

The most destructive insect is the spruce budworm. This insect is a defoliator that attacks both spruce and fir, but prefers fir. Many millions of cords of pulpwood have been lost due to large outbreaks of this insect in the past, primarily in stands containing mature and over-mature fir. Large aerial spraying programs in northern and western Maine have been directed against the spruce budworm in the last several years. Epidemics have not been severe in the characterization area.

The balsam woolly aphid is an introduced insect that is becomming increasingly damaging to fir. The salivary injections of the aphid kill or deform trees.

The important fungal diseases of spruce include red ring rot, which enters through dead branch stubs, and red-brown butt rot, which enters largely through basal wounds (wounds in the lower trunk). These diseases are usually confined to overmature or damaged trees. One fungus, *Stereum sanguinalentum*, causes over 90% of all trunk rot in living balsam fir trees. Often referred to as "red heart," this disease enters the tree through broken tops, broken branches, and other injuries.

In stands where diseases are serious, commercial thinning should begin when tree diameters are about 8 inches (20 cm). The pathological rotation of fir and spruce-fir is 50 to 60 years.

Spruce and fir are shallow rooted. Most of the feeding roots are in the duff (pre-humus ground litter) and the top few inches of mineral soil. Because of their shallow root systems, thin bark, and flammable needles, spruce and fir trees of all ages are easily killed by fire. Their shallow root systems also make them subject to windfall. Caution is necessary in stands subjected to harvesting operations and in areas where windfall is known to be a problem (i.e., coastal peninsulas). Damage can be reduced by leaving uncut portions along the windward edges of the stand. Depth of these protective strips should be a minimum of one-half the height of the trees to be harvested.

MAPLE-BEECH-BIRCH TYPE

Habitat Conditions

Sugar maple, yellow birch, and American beech are the primary timber species in the northern hardwood forests. In older stands, these three species dominate, but younger stands also contain paper birch, white ash, and red maple. Conifers such as eastern hemlock, balsam fir, and red spruce grow with the hardwoods, especially on cool steep slopes and on poorly drained soils at the lower elevations. Repeated cuttings, sometimes followed by wildfires, have favored a variety of stand conditions. Consequently, numerous combinations of stocking levels, age classes, and species are present. Hardwood soils are usually stony and podzolic, but the most productive soils are deep and well to moderately well drained.

Reproduction and Growth

Species in this forest type differ in shade tolerance, longevity, and growth rate. Yellow birch tolerates shade moderately well but usually has the slowest growth. White ash and red maple are also intermediate in shade tolerance but have moderately fast growth rates. Paper birch is one of the fastest growing commercial species but the typical variety is short-lived and very intolerant of shade. Sugar maple, beech, hemlock, and red spruce are all shade-tolerant, long-lived species. Sugar maple and beech have moderate growth rates, whereas hemlock and red spruce are slow growing. Sugar maple, beech, and hemlock are the principal components of the northern hardwood climax forest (Society of American Forester 1967).

The highly shade-tolerant sugar maple and beech dominate the understories of most northern hardwood stands. In contrast, yellow and paper birches need some overhead light and seedbeds of humus or mineral soil for their early establishment and development (Fowells 1965). Paper birch must become dominant in the stand early in life in order to survive to maturity.

Management Methods

Management methods require that a landowner must first decide whether he wants his growing stock to yield top grade products such as veneer logs, sawlogs, and millwood or to yield mostly pulpwood, fuelwood, or other less-valued products. A second basic decision he must make is whether to manage for a high proportion of shade-tolerant species, intermediates, or intolerants. This would have a controlling influence over the silvicultural system used.

Management of uneven-aged stands. Management by uneven-aged stands implemented through selective cutting of individual trees or harvesting of trees in groups of two or three, is recommended for growing a high proportion of shade-tolerant species (i.e., sugar maple, beech, hemlock, and spruce) (Leak et al. 1970; and Tubbs 1968). Selective cutting will produce veneer logs, sawlogs, and millwood, with pulpwood as a byproduct. The public generally accepts selection cutting esthetically because a residual stand always covers the site and disturbance from logging is not as apparent.

To achieve maximum yields, the cuttings are repeated at 10-to 20-year intervals. To develop and maintain a balanced stand structure, a deliberate attempt must be made to mark trees in all diameter classes for cutting. This is not always done because diameter-limit cutting is practiced extensively in the maple-beech-birch forest type in the characterization area.

In many of today's uneven-aged stands, past preferences for certain species in cutting operations and heavy mortality or deterioration in some species (such as beech) from disease attacks have caused considerable variation in structure, stocking, composition, and grade. It may take three or more cyclic cuts (over a given rotational cycle) to improve the productivity of such stands. Yields from improvement cuttings may contain 55% or more low-value products (Filip 1967). In subsequent cuttings the yield should be mostly top-grade products (see "Fuelwood," below).

Often unmerchantable sized classes need additional cultural work to improve species composition, especially to reduce the over-abundance of beech in favor of the higher-value sugar maple. Removing trees above 2 inches (5 cm) dbh may be necessary.

Management of even-aged stands. Management of even-aged stands is recommended for growing a high proportion of intermediate and intolerant northern hardwoods. Among these the commercially important species are yellow birch and white ash (intermediates), and paper birch (intolerant). When managed appropriately, even-aged stands will produce top-grade products. This form of management, as stated previously, is also well suited for pulpwood production, particularly in view of the trend toward more mechanization in harvesting.

Special attention must be given to cutting and cultural practices where high proportions of birches are to be naturally regenerated. Generally, complete stand removal is necessary for successful stand establishment. Complete stand removal can be done in patches, strips or blocks. In each case, the harvesting of merchantable trees is followed by mechanical or chemical removal of all unmerchantable trees above 2 inches (5 cm) dbh.

Patches range from 0.1 to 0.75 acre (0.04 to 0.3 ha) in size. Patch cuttings encourage the regeneration of both yellow and white birch and are appropriate when used in combination with selective cutting under uneven-aged stand management. Groups of mature, overmature, or defective trees are used as nuclei for the patches (Gilbert and Jensen 1958).

Optimum conditions for regenerating white ash have not been determined experimentally; however, conditions that are favorable for yellow birch regeneration tend to be favorable for white ash regeneration, also.

Strip cutting is similar to patch cutting, but is more feasible to apply over large areas. Strips are particularly favorable for regenerating yellow birch (ratios as high as 10 yellow birch to 1 paper birch have been obtained). Strips can be 50 to 100 feet (15 to 30 m) wide. For best yellow birch regeneration, they should be about 50 feet (15 m) wide and oriented in an east-west direction.

Block cutting is more favorable for regenerating paper birch than yellow birch. This cutting method results in regeneration composed of approximately 2/5 paper birch, 1/5 yellow birch and white ash, and 2/5 sugar maple and beech (Leak and Wilson 1958). A seed source must be available to insure prompt and adequate natural birch regeneration. Adjacent stands can provide the seed source in block cuttings up to 10 acres (4 ha). In larger blocks the cutting should be done between September and April during a good seed year to take advantage of the seed from harvested trees. Birch seeds usually do not remain viable beyond the first growing season (Fowells 1965).

Birch regenerates best on disturbed seedbeds where mineral soil is partially exposed or mixed with humus (Barrett 1962; Marquis 1965; and Filip 1967). If about 50% of the soil surface is not disturbed during the logging operation, additional scarification (breaking up the surface) should be considered. Seedbed preparation with power equipment provides the desired mineral soil-humus mixture, and also removes much unwanted vegetation that can suppress newly established birch seedlings.

Productivity of even-aged stands is increased considerably and rotations are shortened by periodic thinnings (see "Fuelwood," below). Stocking guides, based on mean stand diameter and basal area per acre, coupled with stand prescriptions, are used to determine when and how much to thin and when to make the final harvest cutting (Leak et al. 1970; and Solomon and Leak 1969). Basal area, the area in cross section at breast height of a single tree or of all the trees in a stand, is usually expressed in square feet.

Natural Enemies

Northern hardwoods have several natural enemies. One of these is beech bark disease caused by beech scale insect infestation, which may be followed by infection by the parasitic bark fungus *Nectria coccinea* var. *faginata*. This is a lethal disease and is the chief obstacle to producing high quality beech logs.

Birch dieback is an unidentified disease that destroyed thousands of square miles of yellow and paper birch in the New England States and Eastern Canada during the 1930s and 1940s. Dieback has caused the virtual disappearance of birches in some areas (Hepting 1971). Although the disease has subsided in recent years, a recurrence is possible. A similar condition, postlogging decadence, often develops in birches excessively exposed by heavy partial cutting.

The saddled prominent caterpillar has defoliated large areas of northern hardwood stands in the characterization area in recent years. Most hardwoods can withstand 2 to 3 years of moderate defoliation and still recover (Houseweart and Dixon 1977) but severe defoliation can kill trees in one season.

Most fungi that cause decay in living trees are found only in heartwood. A number of such organisms cause cull in birch but some grow outward from heartwood into sapwood and cambium. These decay fungi cause trunk cankers. Several wood-rotting fungi are possible causes of cankers on birches. Among them is *Poria obliqua*. Birch is also susceptible to several fungi that are known to be canker-producing, especially *Nectria galligena*. A number of canker diseases also occur on the various species of maple. The most common ones are caused by *Nectria strummela*, and *Eutypelaa parasitica*.

WHITE PINE-HEMLOCK-HARDWOOD TYPE

Habitat Conditions

This forest type is composed chiefly of eastern white pine, eastern hemlock, beech, sugar maple, red maple, yellow birch, white ash, paper birch, red spruce, and northern red oak. White pine was the species most eagerly sought by loggers in the original forests of the coastal zone and economically is still the most important forest species.

In the virgin forest white pine was dominant on soils inclined to be droughty, such as eskers, kames, outwash plains, and shores and terraces of old glacial lakes (Braun 1950). Elsewhere the development of stands heavily stocked with white pine was the consequence of forest catastrophies. Fire played a major role in establishing essentially even-aged stands of white pine in the original forest by eliminating competition (Cline and Spurr 1942). People also were greatly responsible for the creation of the white pine region along the coast. The farm clearings which they carved out of the wilderness and subsequently abandoned were often reclaimed by white pine forests.

On sandy relatively dry sites, white pine stands may form a climax forest. On fertile and relatively moist soils white pine eventually is displaced by more shade-tolerant species, usually hardwoods. Although white pine may play an ecological role similar to that of some of the most light-demanding species, it is in fact intermediate in shade tolerance.

Reproduction and Growth

White pine begins to bear cones before it is 20 years old, but optimum seed-bearing age is not until 50 to 150 years (Fowells 1965). Condition of the seedbed is an important factor in regenerating white pine. In full sunlight favorable seedbeds are moist mineral soil, moss, or short grass cover of light-to-medium density. Unfavorable seedbeds include dry soil, coniferous litter, lichen, and very thin or very dense grass covers (Smith 1951; and Fowells 1965).

White pine has several attributes that enable it to take advantage of certain conditions and endure in the forest community. First, its seed will germinate well and survive on almost any type of seedbed under shade (Smith 1951). Following establishment the young plants must be given abundant overhead light for best development. They have the ability to withstand exposure without suffering undue mortality. Second, young seedlings are exceptionally drought resistant, having the capacity to survive extended periods of drought (Smith 1951). Third, height growth may be very rapid once the seedling is established and in the open. On the best sites, annual height growth of 2 to 3 feet (0.6 to 1 m) or more has been observed after trees have reached breast height.

Management Practices

Growth characteristics of white pine are such that it is best grown under even-aged stand conditions but considerable flexibility may be exercised in choosing regeneration methods. The method most successfully employed is known as a two-cut shelterwood system. The following steps are taken in this system:

1. An initial cut is made in an established stand of trees during, or immediately after, an abundant seed year. This cut consists of removing 40% to 60% of the overstory. It is important that the first cut result in the disturbance of accumulated litter and the exposure of mineral soil so that the seed can germinate and grow.

2. A second cut is made to remove the shelter trees, usually 5 to 10 years after the first cut. Seedlings by this time have become established and have entered their rapid growth period.

Corrective measures must accompany the harvest of trees if pine is to be perpetuated in a stand. Before the first cut, hardwood saplings must be removed. This has been done in the past most economically by spraying 2,4,5-T (see discussion in "Spruce-Fir Forest Type" for alternative herbicides). If this measure is not taken, hardwoods will be released, will grow very rapidly, and will shade out young pine seedlings when the stand is opened. Before or immediately after the second cut the area must be examined to determine whether white pine has become adequately established. Hardwood seedlings should be removed at this time if they have become established to an extent that would interfere with the rapid growth of, or threaten the survival of, pine. Light to moderate livestock grazing served these purposes inadvertently in the past. White pine can be grown on every soil type in the Maine coastal zone with the exception of heavy clay soils. Since competition from hardwoods is an important factor in establishing pine, it must be considered in choosing to manage pine. Hardwood offers the least competition on excessively-drained and well-drained sandy soils and on droughty, loamy sands.

No firm rules exist for selecting a forest site for hardwood or white pine management. Over a rotation white pine will outgrow hardwood on the good and poor sites but if growing pine on good hardwood sites is unprofitable economically, growing it on poor or light soils may be a wiser choice. This practice not only provides for sufficient representation of both hardwood and white pine, but also facilitates the task of developing a greater proportion of white pine (Lutz and Cline 1947).

Yields of white pine stands vary with soil condition and other factors that influence overall site quality. Site quality is determined from site-index curves shown in figure 19-2, which shows the height of dominant trees plotted over age for several site-index classes.

Volumes (by stand age and site indexes) for pure white pine stands near the upper limit (for practical management) of stocking are given in table 19-6 (Leak et al. 1970). Yields increase markedly with age and site index and will be higher or lower depending on stand stocking. Yields of white pine will drop as the proportion of hardwood increases.

Growth rates in white pine stands may vary greatly with site condition and stocking density. The average white pine stand will grow from 300 to 800 board feet (1" x 12" x 12")/acre/year. Study plots on exceptionally good sites have shown yearly growth rates as high as 1200 board feet/acre for site index 60, and as high as 1600 board feet/acre for site index 80. These growth rates represent optimum conditions in small, well-stocked stands (Leak et al. 1970).

Natural Enemies

Quality white pine is always in commercial demand but finding high quality material is difficult in the characterization area, as it is in most of the white pine range.

One of the major limiting factors affecting the quality of white pine is the white pine weevil. This insect attacks and kills the terminal (central) shoot of the tree. The resulting injury seldom causes deaths of the trees, but lateral branches competing for the position formerly held by the terminal leader inevitably produce a crook in the stem, which ultimately lowers log quality. The rapidity with which one lateral shoot asserts its dominance over the others determines the degree of the crook. Often two laterals compete long enough to establish a forked tree. In addition to causing crooks, weevil injury also causes a loss in stem length, affecting 2 or 3 years of growth. Lumber defects caused by weevil injury are cross-grain, red rot, large branch knots, and loose knots.

Several techniques are used for controlling white pine weevil damage. Chemical sprays can be used safely provided that precautions are observed with applications and dosage, and that only properly registered insecticides are used. Spraying from the ground is expensive and aerial spraying in the spring has not proved successful. Recent research performed on young white pine plantations in Penobscot County by the University of Maine's School of Forest Resources indicates that fall spraying may offer promise to greatly reduce insect numbers (Cooperative Forestry Research Unit 1979).

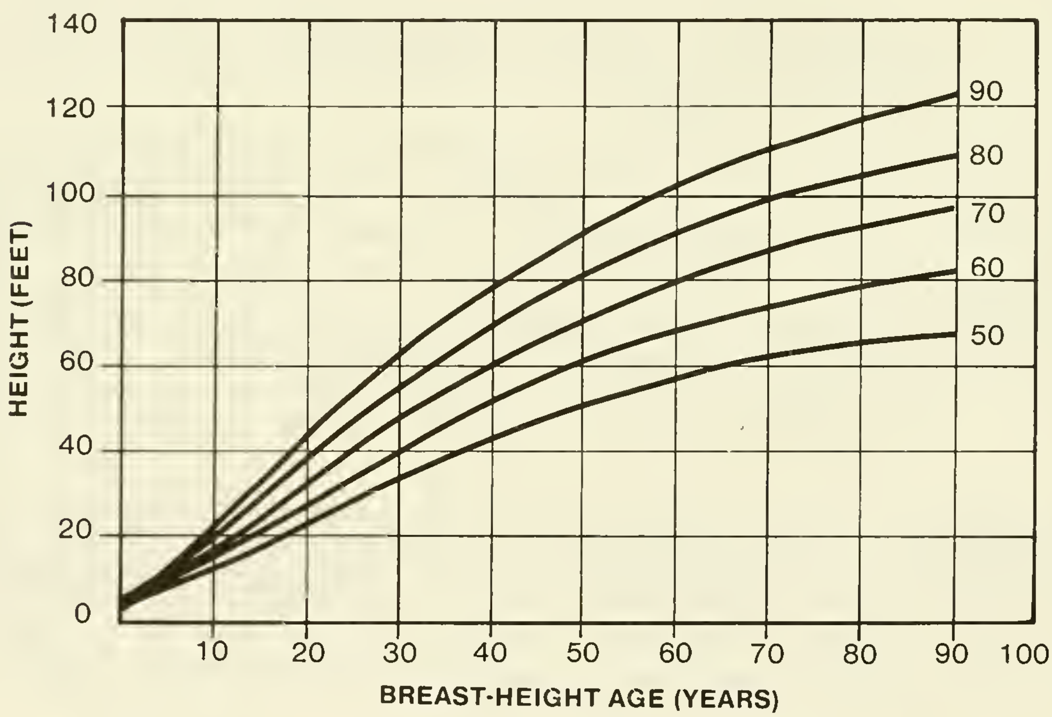

Figure 19-2. Site index curves for eastern white pine in New England (curves corrected to breast-height age of 50) (Frothingham 1914).

Table 19-6. Yields, by Stand Age and Site Index, for Stands of New England White Pine at the Upper Level of Stocking, in Board Feet/acre and in Cubic Feet/acre[a]

Stand age	Site index 50		60		70		80		90	
20		1423		1667		1952		2286		2677
40	7729	3526	10,748	4129	14,948	4836	20,788	5663	28,909	6632
60	16,858	4771	23,444	5587	32,604	6543	45,342	7663		8974
80	23,898	5550	34,625	6499	48,152	7611	66,965	8914		10,439
100	31,460	6077	43,752	7116	60,845	8334	84,617	9760		11,431

[a] Leak et al. 1970.

The major tree disease in the coastal zone is the blister rust which occurs when white pine is grown near Ribes species, such as currants or gooseberries. The fungus grows through the needle or new shoot into the branch and from there into the trunk where it produces a girdling, killing canker. Orange blisters filled with spores appear on these cankers in the spring and spores are liberated when the blisters break. The spores then infect Ribes leaves and the cycle begins again.

White pine should not be planted in an area where Ribes grow unless the Ribes bushes are removed from the planting site and from an area 900 feet (273 m) wide around it. Ribes should be removed in stands of white pine where blister rust occurs. Losses in infected stands can be minimized by removing stem-cankered trees and pruning the others to reduce the possibility of the rust reaching the trunk through one or more lower branches.

FUELWOOD

Recent price increases and scarcity of fuel oil has stirred interest in heating with wood. A 1978 survey by the Maine Audubon Society revealed that 46% of Maine's households are currently heating entirely or partially with wood and the average annual consumption of wood per household was 3.6 cords. This use of wood for heating represents a net increase in the State's total wood consumption.

Species Used

The species most used for heating are those with the highest BTU values, such as oak and maple (table 19-7). The species are present in all of the forest types previously described, but they are most indigenous to the northern hardwood type. Silviculturally, the ideal way to produce fuelwood is by selectively thinning hardwood stands. This method, when properly applied throughout the life of the stand, will yield adequate amounts of fuelwood and permit the most valuable species in a stand to grow rapidly throughout their lives. Removal of less valuable competing trees enables the stand to ultimately produce large, high quality trees that can be sold at rotation age for veneer, sawlogs, and other valuable products.

The monetary value of the species in a stand must be known before thinning can begin (table 19-8). Sugar maple, white ash, yellow birch, and white birch, usually, are more valuable than red maple, beech, and aspen. The higher-valued species should be favored to remain uncut in the stands.

Silvicultural Methods

Thinnings should begin as early as possible so that the benefits of repeated thinnings may be gained. The best time to begin thinning a hardwood stand is when the trees average 4 to 10 inches (10 to 25 cm) in dbh. Trees of this size class, commonly referred to as poles, respond rapidly to thinning because intense competition from surrounding trees has begun to slow their growth. Even larger trees, averaging 10 to 12 inches (25 to 50 cm) dbh, should sometimes be thinned. These hardwood stands are approaching commercial sawtimber size and some of the high quality thinned trees can probably be sold as sawlogs.

Table 19-7. Approximate Weight, Moisture Content, and Available Heat Units of Selected Woods, Green and Air-dry[a]

Species	Weight[b] (lbs) Green	Air-dry	Available heat units per cord in million BTUs[c] Green	Air-dry	Equivalent fuel oil per cord of wood Gallons[d]
Quaking aspen	3440	2160	10.3	12.5	74
White pine	2880	2080	12.1	13.3	79
American elm	4320	2900	14.3	17.2	102
Paper birch	3800	3040	16.7	18.3	108
Red maple	4000	3200	15.0	18.6	111
White ash	3840	3440	16.5	20.0	119
Sugar maple	4460	3680	18.4	21.3	127
Northern red oak	5120	3680	17.9	21.3	127
Yellow birch	4560	3680	17.3	21.3	127
American beech	4320	3760	17.3	21.8	130

[a] University of Wisconsin Extension 1977 .

[b] Per standard cord (4' X 4' X 8') containing 80 cu feet of solid wood.

[c] Moisture content approximately 20%.

[d] Using air-dry wood at 50% heating unit efficiency, oil 65%.

Table 19-8. Average Stumpage Price by Species for Sawtimber and Pulpwood, March 1979[a]

Species	Sawtimber $/1000 bd ft	Pulpwood $/cord
Softwoods		
White pine	56	4.25
Red pine	42	4.00
Pitch pine	37	----
Hemlock	33	5.25
Spruce	43	7.95
Balsam fir	40	7.95
Northern white cedar	29	----
Tamarack	27	5.25
Hardwoods		
White birch	54	5.00
Yellow birch	49	5.00
Sugar maple	52	5.00
Oak	65	5.00
Beech	30	5.00
Aspen	29	4.75
Basswood	24	5.00
Elm	26	5.00
Red maple	28	5.00
White ash	74	5.00
Brown ash	18	5.00

[a] Maine Bureau of Forestry.

The preferred way to thin a young pole stand is the "crop tree selection method." This is a simple method of thinning stands to the advantage of the best trees (i.e., crop trees) in the stand. First, trees selected as crop trees should be a valuable species. They should be straight, tall, have relatively small branches, and should show signs of self-pruning (the lower 10 to 16 feet, or 3 to 5 m, of the tree should have few or no branches). The crown of a crop tree needs 3 to 4 feet (1 to 1.2 m) of open space on at least two sides. Trees touching the crown of crop trees are competitors. In harvesting fuelwood these should be the first trees removed since they are direct competitors. The trees to be removed in some stands may be as high quality as the crop trees. But, they would be shaded out by crop trees in the future and die anyway. Furthermore, the crop trees released will grow faster and will regain some of the growth lost by removing competitors.

Small understory trees are abundant in most pole stands. Their crowns are lower than the crowns of larger trees so they are usually deprived of direct sunlight. The larger understory trees may be cut for fuelwood. Their removal will have little effect on the growth of crop trees but they are useful as fuelwood supplies.

After releasing the crop trees any remaining dead, dying, and deformed trees which hinder development of the stand should also be harvested for fuelwood.

CHRISTMAS TREE PRODUCTION

The Christmas tree and wreath businesses are important sources of income for many people in the Maine coastal zone. Christmas trees, brush for decorations, and tips for wreaths are cut in natural stands and plantations each fall. Reliable production and cost data by species and geographic region within Maine are not available.

The primary species used is balsam fir because of its strong fragrance, soft dark-green foliage, good shape, and excellent needle-retention capacity.

RESEARCH NEEDS

The increasing demand for paper, paper products, and building materials, relatively heavy recreational use, suburban development, and the high cost of land ownership, results in the need for growing more and better quality trees on less land while still considering wise environmental protection practices. It is imperative that new, environmentally sound methods of shortening rotations and raising tree quality be developed and used.

The following is a list of basic silvicutural considerations and data gaps to be investigated for the coastal zone:

1. Acreages and land ownership patterns by forest type and intensity of management practices should be determined.
2. The effect of redistributing logging slash and removing above-ground portions of the tree on nutrient levels.
3. The environmental implications of spraying 2,4,5-T. Perhaps even more important, the environmental impacts of spraying substitute

herbicides if 2,4,5-T is permanently banned for use in forestry practice.

4. The amount of erosion and stream siltation resulting from different harvesting and cutting methods.
5. The effect of spraying insecticides to suppress spruce budworm on the total insect population and their predators.
6. The effect of monocultures (single species stands), especially tree plantations that may include introduced species, on native flora and fauna populations.
7. The effect of fuelwood harvesting on total forest resources.

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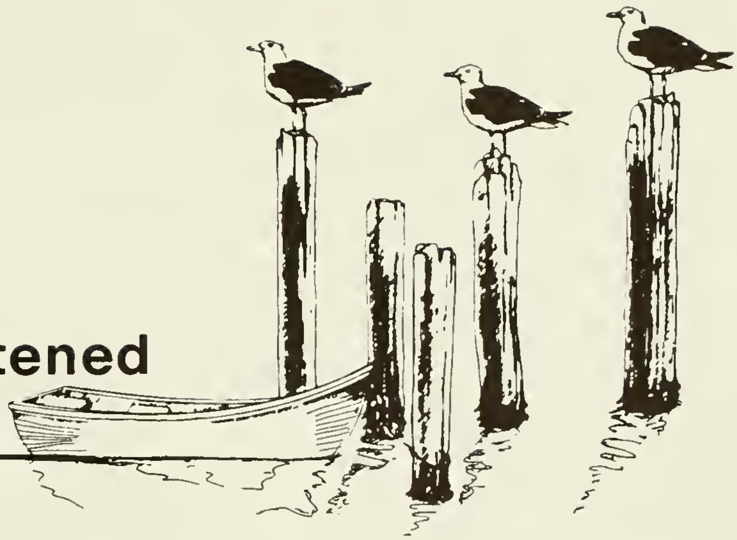
Chapter 20
Endangered, Threatened and Rare Plants



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Endangered species are those considered in danger of extinction throughout all or a significant portion of their range. Threatened species are those likely to become endangered within the forseeable future throughout significant portions of their ranges and rare plants are those having small or restricted populations in particular areas of their ranges, but are not endangered.

A variety of the estuary monkey flower (Mimulus ringens var. colpophilus), found in some estuaries in coastal Maine and Canada, was recently considered endangered by the U.S. Fish and Wildlife Service (FWS). Six other plants found in coastal Maine were listed as threatened by the Smithsonian Institute (table 20-1; Ayensu and DeFilipps 1978). These species are no longer listed as endangered or threated because critical habitats in which they are found were not identified (see "Protection of Endangered, Threatened, and Rare Plant Species" below). Another 84 plant species are considered rare in Maine by either the Maine State Planning Office, the New England Botanical Club, or plant taxonomists familiar with the species (table 20-2).

Plants are usually considered endangered if they have very limited distributions, or if they are found in restricted or fragile habitats. Plants also may be endangered because of destruction, alteration, or curtailment of their habitat, or because of exploitation, disease, or unknown causes. Rare plants may be rare throughout their ranges, or they may be rare only on the fringes of their ranges. Most species considered rare in Maine are on the periphery of their normal ranges and may be relatively common elsewhere.

Endangered, threatened, and rare plants may occur in relatively undifferentiated habitats, such as mature deciduous forests and mature spruce-fir forests, or they may be found in locally unique, unusual, or isolated habitats (Ayensu and DeFilipps 1978). The latter habitats may be ecologically or geographically restricted, fragile, or otherwise specialized due to various combinations of climatological, geological, hydrological, and biological factors. Unique or specialized habitats in coastal Maine that support rare plants include plateau bogs, forested wetlands dominated by Atlantic white cedar or northern white cedar, coastal headlands and islands, palustrine and riverine wetlands, and estuaries.

Table 20-1. The Scientific and Common Names, Habitat, and Status of Endangered and Threatened Herbaceous Plant Species in Coastal Maine, Listed by The Smithsonian Institution[a]

Taxonomic name: Species	Family	Common name	Habitat[b]	Overall status[c]	Life span[d]
Endangered					
Mimulus ringens L. var. *colpophilus* Fern.	Schrophulariaceae	Estuary monkey flower	F	V	P
Threatened					
Cypripedium arietinum R. Br.	Orchidaceae	Ram's-head lady's-slipper	S	R	P
Listera auriculata Wieg.	Orchidaceae	Auricled twayblade	W	R	P
Habenaria flava var. *herbiola* (R.Br.) Ames & Correll	Orchidaceae	Pale green orchis	M	R	P
Panax quinquefolius L.	Araliaceae	Ginseng	D	X	P
Carex oronensis Fern.	Cyperaceae	Orono sedge	O	R	P
Cardamine longii Fern.	Cruciferae (Brassicaceae)	Long's bittercress	F	V	B

[a]Avensu and DeFilipps 1978.
[b]Habitat: F=freshwater estuaries; S=shaded woods; W=wet woods and river banks; M=meadows, thickets, woods; D=deciduous woods; O=open areas and dry ground.
[c]Overall Status: V=very rare; R=rare; X=commercially exploited.
[d]Life span: P=perennial; B=biennial.

Table 20-2. Rare Plant Species of Coastal Maine[1]

Common and Taxonomic names	Family name	Atlas Number	Habitat
Calypso bulbosa (L.) Oakes Calypso	Orchidaceae	8[2]	Deep, moist coniferous woods
Lycopodium selago L. Mountain club-moss	Lycopodiaceae	9[2]	Mossy rocks, barrens, cold woods
Botrychium lunaria (L.) SW. Moonwort	Ophioglossaceae	10	Open turfy, gravelly, or ledgy slopes and shores
Ophioglossum vulgatum L. var. pseudopodum (Blake) Farw. Adder's tongue	Ophioglossaceae	11	Peaty or grassy patures, meadows and wet thickets
Asplenium trichomanes L. Maiden-hair spleenwort	Polypodiaceae	13[2]	Shaded rock crevices
Dryopteris fragrans (L.) Scott var. romotiuscula Kamarov Fragrant cliff-fern	Polypodiaceae	14[2]	Dry cliffs and rocky banks
Athyrium thelypterioides (Michx.) Desv. Silvery spleenwort	Polypodiaceae	15	Rich woods, bottom lands, and shaded plots
Pinus banksiana Lamb. Jack pine	Pinaceae	16	Barren, sandy, or rocky soil
Chamaecyparis thyoides (L.) BSP. Atlantic white cedar	Cupressaceae	17[3]	Palustrine forested wetlands
Juniperus horizontalis Moehch. X J. Virginiana L. Hybrid juniper	Cupressaceae	18	Coastal rocky ledges
Zannichellia palustris L. var. Major (Boenn.) D.J. Koch Horned pondweed	Najadaceae	19	Fresh, brackish or alkaline waters
Scirpus cylindricus (Torr.) Britt. Bulrush	Cyperaceae	20	Brackish emergent wetlands and brackish shorelines
Eleocharis rostellata Torr. Spike-rush	Cyperaceae	21	Brackish and saline emergent wetlands

[1]Nomenclature after Fernald 1950.
[2]Botanical fact sheets available from Critical Areas Program
[3]Planning reports available from Critical Programs

(continued)

Table 20-2. (continued),

Common and taxonomic names	Family name	Atlas Numbers	Habitat
Carex atherodes Spreng. Sedge	Cyperaceae	22	Calcareous meadows, shores palustrine emergent meadows
C. rariflora (Wahlenb.) Sm. Sedge	Cyperaceae	23	Bogs and pond margins, peaty barrens
Wolffia columbiana Karst. Water-meal	Lemnaceae	24	Floating beneath quiet waters
Eriocaulon parkeri Robins. Pipewort	Eriocaulaceae	25[2]	Brackish and saline tidal mud
Juncus dudleyi Wieg. Rush	Juncaceae	26	Damp calcareous soils
J. alpinus Vill. Rush	Juncaceae	27	Wet shores, emergent wetlands (palustrine)
Allium canadense L. Wild garlic	Liliaceae	28	Low woods, thickets and meadows
Aletris farinosa L. Unicorn-root	Liliaceae	29	Dry or moist peats, sands and gravels
Iris hookeri Penny Beachhead iris	Iridaceae	30[2]	Headlands, rocky slopes beaches, dunes within reach of salt-spray
I. prismatica Pursh Slender blue flag	Iridaceae	31[3]	Brackish or saline emergent wetlands near coast
Goodyera pubescens (Willd.) R.Br. Downy rattlesnake plantain	Orchidaceae	32	Dry or moist woods
Arethusa bulbosa L. Dragon's mouth	Orchidaceae	33a[2]	Sphagnous bogs and peaty emergent meadows
A. bulbosa forma albiflora Rand & Redfield Dragon's mouth	Orchidaceae	33b	Sphagnous bogs and peaty emergent wetlands (scrub-shrub)
A. bulbosa forma subsaerulea Rand & Redfield Dragon's mouth	Orchidaceae	33c	Sphagnous bogs and peaty emergent wetlands (scrub-shrub)

Table 20-2. (continued)

Common and taxonomic names	Family name	Atlas Number	Habitat
Spiranthes gracilis (Bigel.) Beck Southern slender ladies' tresses	Orchidaceae	34	Sterile open soil, thickets, open woods
Betula caerulea-grandis Blanch. Blue birch	Betulaceae	35	Dry woods
Castanea dentata (Marsh.) Borskh. American chestnut	Fagaceae	36	Dry, rocky acid deciduous woods
Geocaulon lividum (Richards.) Fern. Northern comandra	Santalaceae	37	Moss or damp humus, coastal plateau bogs
Montia lamprosperma Cham. Blinks	Portulacaceae	38	Springy wet shores, brackish shores
Arenaria groenlandica (Rentz.) Spreng. Mountain sandwort	Caryophyllaceae	39[2]	Granitic ledges and gravels on coastal headlands, islands and mountain tops
Nuphar microphyllum (Pers.) Fern. Yellow pond-lily	Nymphaeaceae	40	Pond-margins and deadwaters (palustrine, lacustrine, and riverine)
Ranunculus ambigens S. Wats. Water plantain or spearwort	Ranunculaceae	41	Sloughs, ditches and muddy palustrine emergent wetlands
Clematis verticillaris DC. Purple clematis	Ranunculaceae	42	Rock slopes and open woods
Sassafras albidum (Nutt.) Nees. Sassafras	Lauraceae	43	Woods and thickets
Adlumia fungosa (Ait.) Greene Climbing fumitory	Fumariaceae	44	Recently burned woods and rocky wooded slopes
Dentaria maxima Nutt. Toothwort	Brassicaceae	45	Wooded streams and calcareous wooded slopes (riverine and lacustrine)
Subularia aquatica L. Awlwort	Brassicaceae	46	Slow streams and sandy margines of lakes
Arabis missouriensis Greene Rock cress	Brassicaceae	47	Bluffs, ledges, and rocky woods (northern)

Table 20-2 (continued)

Common and taxonomic names	Family name	Atlas Number	Habitat
Podostemum ceratophyllum Michx. Thredfoot	Podostemaceae	48	On rocks in streams (riverine)
Sedum ternatum Michx. Stonecrop	Crassulaceae	49	Damp, often calcareous rocks, brooksides, etc.
Sedum rosea (L.) Scop. Roseroot	Crassulaceae	50	Along rocky coast and cliffs
Saxifraga pensylvanica L. Swamp thickets	Saxifragaceae	51	Sphagnous palustrine scrub-shrub emergent wetlands (boggy thickets and swamps)
Amelanchier interior Nielson. Shadbush or Juneberry	Rosaceae	52	Hillsides and banks of streams
Crataegus ideae Sarg. Hawthorn	Rosaceae	53	Old fields, thickets, and open woods
Rubus chamaemorus L. Baked-apple-berry	Rosaceae	54	Coastal plateau bogs (palustrine emergent scrub-shrub wetland)
Astragalus alpinus L. var. bronetianus Fern. Milk-vetch	Fabaceae	55	Gravelly river banks
Polygala cruciata L. var. aquilonia Fern & Schub.	Polygalaceae	56	Damp peat, sands, sterile meadows near coast
Empetrum atropurpureum Fern. & Wieg. Purple crowberry	Empetraceae	57	Granitic or acidic gravel & sands along coast (coastal plateau peatlands?)
Ilex glabra (L.) Gray Inkberry	Aquifoliaceae	58[3]	Bogs (palustrine scrub-shrub wetland), low sandy and peaty soil

Table 20-2. (continued)

Common and taxonomic names	Family name	Atlas Number	Habitat
Ceanothus americanus L. New Jersey tea	Rhamnaceae	59[3]	Dry open woods, gravelly or rocky banks
Viola brittoniana Pollard Violet	Violaceae	60	Sandy or peaty soil
Viola triloba Schwein. Violet	Violaceae	61	Rich woods, shaded ledges (mostly calcareous)
Dirca palustris L. Wicopy	Thymelaeaceae	62	Rich deciduous or mixed woods
Nyssa sylvatica Marsh. Black gum or sour gum	Cornaceae	63	Dry or moist woods and palustrine forested wetlands
Lilaeopsis chinensis (L.) Ktze. No common name	Apiaceae (Umbelliferae)	64[2]	Brackish estuarine emergent wetlands and tidal mud
Clethra alnifolia L. Sweet pepperbush	Clethraceae	65	Palustine shrub-scrub wetlands, damp thickets
Rhododendron viscosum (L.) Torr. Swamp honeysuckle	Ericaceae	67	Palustine shrub-scrub wetlands, thickets, and damp clearings
Kalmia latifolia L. Mountain laurel	Ericaceae	68[3]	Rocky or gravelly deciduous woods and mixed woods
Vaccinium caesariense Mackenz. Highbush blueberry	Ericaceae	69	Palustine scrub-shrub wetlands (swamp, peaty thickets and bogs)
Hottonia inflata Ell. Featherfoil	Primulaceae	70	Pools (palustrine open water) and ditches
Primula laurentiana Fern. Bird's-eye primrose	Primulaceae	71	Seacliffs, ledges near coast (calcareous elsewhere)
Samolus parviflorus Raf. Water-pimpernel	Primulaceae	72[2]	Shallow brackish water, wet, muddy soils inland

Table 20-2. (continued)

Common and taxonomic names	Family name	Atlas Number	Habitat
Gentiana crinita Froel. Fringed gentián	Gentianaceae	73	Meadows, brooksides, wet thickets, low woods
Bartonia paniculata (Michx.) Muhl. Screw-stem	Gentianaceae	74	Bogs, wet peat and sand (palustrine scrub-shrub wetlands)
B. paniculata var. *intermedia* Fern.	Gentianaceae	75	Bogs, wet peat and sand (palustrine scrub-shrub wetlands)
Lomatogonium rotatum (L.) Fries Marsh-felwort	Gentianceae	76a[2]	Turfy, sandy seashores
L. rotatum forma *americanum* (Griseb.) Fern.	Gentianaceae	76b	Turfy, sandy seashores
Stachys tenuifolia Willd. var. *platyphylla* Fern.	Lamiaceae (Labiatae)	77	Low woods, rich fresh shores and meadows
Gerardia maritima L. Gerardia	Scrophulariaceae	78[2]	Saline estuarine emergent wetlands
Galium obtusum Bigel. Bedstraw	Rubiaceae	79	Low woods, wet shores, palustrine scrub-shrub wetlands (swamps)
Houstonia lanceolata (Poir.) Britt. Bluets	Rubiaceae	80	Pastures, slopes and dry open woods
H. longifolia Gaertn. Bluets	Rubiaceae	81	Rocky or gravelly soil, pastures
Lonicera oblongifolia (Goldie) Hook. Swamp-fly honeysuckle	Caprifoliaceae	82[2]	Bogs, swampy thickets, wet woods (palustrine scrub-shrub and forested wetlands)
L. sempervirens L. Trumpet honeysuckle	Caprifoliaceae	83	Deciduous woods and thickets
L. dioica L. Honeysuckle	Caprifoliaceae	84	Rocky banks, dry woods and thickets

Table 20-2 (concluded)

Common and taxonomic names	Family name	Atlas Number	Habitat
Lobelia siphilitica L. Great lobelia	Lobeliaceae	85	Palustrine emergent and scrub-shrub wetlands (swamps), low ground
L. kalmii L. Lobelia	Lobeliaceae	86[2]	Wet ledges, freshwater shores, meadows, bogs, often calcareous (palustrine habitats)
Solidago lepida DC. var. fallax Fern. Goldenrod	Asteraceae	87a	Coastal island (open)
S. lepida var. molina Fern.	Asteraceae	87b	Coastal islands (open)
S. altissima L. Tall goldenrod	Asteraceae	88	Pastures, open fields, roadsides
Aster foliaceus L. Aster	Asteraceae	89[2]	Meadows, shores thickets, rocky slopes (coast islands)
Iva frutescens L. var. oraria (Bartlett) Fern. & Grisc. Marsh-elder	Asteraceae	90	Saline emergent marshes (estuarine)
Achillea borealis Bong. Yarrow	Asteraceae	91	Wet rocks, cool slopes
Mikania scandens (L.) Willd. Climbing hempweed	Asteraceae	92	Thickets, swamps, banks of streams (palustrine scrub-shrub and emergent wetlands)
Hieracium venosum L. var. nudicaule (michx.) Farw. Rattlesnake-weed	Asteraceae	93	Open woods, clearings

This chapter summarizes the distribution of the seven species that were previously listed as endangered or threatened in Maine. Geographic ranges, preferred habitats, reproductive characteristics, taxonomic status, interrelationships with other plant and animal species (i.e., pollinators), and the major human-related threats to these species are discussed for each taxon. The rare species are discussed as a group. Rare and unusual plant communities containing three or more rare plant species are also described. Factors affecting abundance and distribution of plants are discussed generally, and data gaps and management problems are summarized. The approximate locations where endangered, threatened, or rare plants are known to occur in coastal Maine are indicated on atlas map 4. Common names of species are used except where accepted common names do not exist. Taxonomic names of all species mentioned are given in the appendix to chapter 1.

DATA SOURCES

Lists of endangered, threatened, and rare plants (table 20-1) were obtained from the Federal Register (16 June 1976), the Smithsonian report (Ayensu and DeFilipps 1978), the Critical Areas Program of the Maine State Planning Office (Eastman 1978a), and the New England Botanical Club (Eastman 1978b). Data on the distribution of these species in Maine were gained from the Critical Areas Program (planning reports, botanical fact sheets, and unpublished data), published literature (Schuyler 1974; Rand and Redfield 1894; Wheary 1938; Wise 1970; and Fasset 1928) and herbarium specimens (Eastman 1978a; and the Academy of Natural Sciences of Phildadelphia).

Data on the geographic ranges, preferred habitats, growth habits, and longevity of these species were obtained from Fernald (1950) and Gleason and Cronquist (1963). Information on reproductive biology, including pollinators, came from published literature and personal communications with specialists.

ENDANGERED AND THREATENED PLANTS

Of the seven species of endangered or threatened plants in coastal Maine, the ram's-head lady's-slipper (Cypripedium arietinum), auricled twayblade (Listeria auriculata), pale green orchis (Habernaria flava var. herbiola), and ginseng (Panax quinquefolius) are considered true species by plant taxonomists, and further research into their distribution and abundance is warranted. The taxonomic status of Orono sedge (Carex oronensis), Long's bitter cress (Cardamine longii), and estuary monkey flower is less certain. Orono sedge is a member of a genus whose species are difficult to distinguish. Long's bitter cress and the estuary monkey flower may be only ecological races and not worthy of taxonomic recognition. Available biological information on these species in coastal Maine is summarized below. Little information is available on most of these taxa.

The Estuary Monkey Flower

The estuary monkey flower is a member of the snapdragon family and is apparently an ecological variant of the more common M. ringens var. ringens. The coastal variety is restricted largely to the upper intertidal zone of estuaries in Maine and the St. Lawrence River estuary in Canada. The more common variety (ringens) is abundant in wet meadows and along the banks of streams throughout Maine. At least one specimen of this variety has been found along each of the following coastal rivers: the Machias River in Machias (region 6), Chandler River in Jonesport (region 6), Penobscot River in Bangor (region 4), Passagassawakeag River in Belfast (region 4), Kennebec River in Topsham (region 2), and at Cape Small Point in Phippsburg (region 2). The last collection was made in 1936 along the Chandler River in Jonesport. Five specimens were collected between 1896 and 1935.

The endangered variety (colpophilus) is recognized as a true variety in the three most recent floras that encompass coastal Maine (Fernald 1950; Gleason and Cronquist 1963; and Seymour 1969). However, H. E. Ahles (personal communication, University of Massachusetts Herbarium, Amherst, MA; November, 1979), who is preparing a flora of New England, suggests colpophilus may be an extreme form of ringens that he would not recognize as taxonomically distinct. Experimental evidence, including reciprocal transplants, and critical analysis of key vegetative and reproductive characters would be required to resolve the taxonomic status of this variety.

Reproduction in the estuary monkey flower is primarily sexual, however short rhizomes used in asexual reproduction are produced also. The flowers are blue, somewhat showy, and asymmetrical in shape. Pollination is done by bees. The flowering period is June through August and the fruit matures between July and September. The fruit capsule opens passively along horizontal sutures. No data are available on seed predation but insects and small mammals are the most likely predators.

Oil spills, tidal power, hydroelectric power, and trampling pose the greatest threat to the estuary monkey flower. Plants of the more common variety (ringens) exposed to oil in Connecticut were completely eliminated after one growing season (Burk 1977).

Ram's-Head Lady's-Slipper

The ram's-head lady's-slipper, a threatened orchid, inhabits mixed forests and open white cedar forests. It is found in moist, well-aerated, shady soil. This species' range extends from Nova Scotia and northern New England, west through Quebec, Ontario, and the Great Lakes. It is rare throughout its entire range (Luer 1975).

The ram's-head lady's-slipper has been collected in coastal Maine at Cape Elizabeth, South Portland, Gardiner, Bucksport, and Orland. It also has been collected in the nearby townships of Wayne, Old Town, New Gloucester, and Manchester. An estimated 200 to 300 plants were found recently in Wayne (Brower 1977). This is the largest number of plants record in Maine thus far.

Reproduction in this plant is both sexual (by seeds) and asexual (by offshoots). The flowers are pollinated by bees which are attracted to the flowers by strong odors (no nectar is contained in these flowers). Upon landing on a flower the bees may fall into a pouch and are forced to crawl out under the reproductive structures where cross-fertilization occurs.

Lumbering, plant collecting, and trampling pose the greatest threats to the ram's-head lady's-slipper. Insecticides also are a threat because they may be toxic to bees which are necessary for fertilization.

Auricled Twayblade

The auricled twayblade, another threatened orchid, is a diminutive herbaceous monocot that usually inhabits alder thickets. It is found from northern New England to northern Michigan, and northward to the Canadian subarctic. The only collections of this plant in coastal Maine were made on Mt. Desert Island (region 5) in 1891 and 1927. Its current status is unknown. It has been collected at 18 locations in Maine outside the coastal zone, but not in recent years.

Little biological information is available on this species. Other species of this genus reproduce both sexually (seeds) and asexually (short rhizomes that elongate after flowering). Flowers of the auricled twayblade bloom in July and the fruit capsules mature within a week of fertilization. Twayblades are pollinated by mosquitos, small moths, beetles, and ichneumonid wasps (van der Pijl and Dobson 1966; and Darwin 1877). The pollen is contained in two simple masses called pollinia, which, in *Listera*, are explosively released at the touch of a pollinator. A droplet of a glue-like material from the pollinia dries solidly within a few seconds and fixes the pollinia to the pollinator. There is no evidence this species forms a close association with a specific species of pollinator. Twayblades produce seeds profusely. Seed predators probably include insects and small mammals.

Flooding, peat mining, stream channeling, and logging pose the greatest threats to this species.

Pale Green Orchis

The pale green orchis is a threatened orchid of which *herbiola* is the only variety found in Maine. This species is also placed in the genus *Platanthera* *P. flava* (L.) Lindley var. *herbiola* (R. Brown) Luer . It grows in low, wet, woods, moist thickets, and along marshy banks. It is often found in shallow water with a thick layer of decaying leaves (Luer 1975). It's range extends from Nova Scotia to Wisconsin, and south to Florida and the Gulf States. The northern variety (*herbiola*) is found from Kentucky and western North Carolina north. It has been found in four locations in the coastal zone: West Dresden in region 2 (1973); Monhegan in region 3 (1964); and Rockport (1935) and Frankfort (1916) in region 4. It has been collected in the adjacent townships of Clinton (1914 and 1916), Vassalboro (1916), and in 20 other areas in Maine. The varieties *flava* and *herbiola* intergrade where their ranges overlap (Luer 1975).

Reproduction in the pale green orchis is entirely sexual. It is pollinated by small moths and *Aedes* mosquitos (van der Pijl and Dobson 1966). As with *Listera*, the pollen is borne in two masses; the pollinia, which become attached to the insect. The flowering period is between July and early August.

Lumbering, flooding, stream channeling, and plant collecting pose the greatest threats to the pale green orchis.

Ginseng

Ginseng is not rare throughout its entire range but is very rare in the coastal zone and is threatened by commercial exploitation. The root of ginseng is harvested and exported to the Orient. The root is alleged to be an aphrodisiac, to prolong life, to increase mental capacities, and to lessen fatigue. An estimated 221,000 lb (100,500 kg) of ginseng root were exported from the United States to Hong Kong in 1974. Ginseng was dug commercially in Maine during the 1800s and early 1900s and digging ginseng was a common practice among woodsmen, guides, and trappers in the Oakland area (adjacent to region 2) during the 1920s (Eastman 1976a). No data on annual commercial harvest in Maine are available. Ginseng inhabits mature deciduous forests, and is usually found in the shade of sugar maple (Acer saccharum), American beech (Fagus grandifolia), basswood (Tilia americana), hop hornbeam (Ostrya virginiana), or white ash (Fraxinus americana). It has been collected at 14 locations in Maine. One of these (Gardiner, region 2) is in the coastal zone where a collection was made by A. R. Norton in 1912. Three others are near region 2 (Clinton, Oakland, and Fayette). The current status of the Gardiner site is unknown because the original collection site was not documented.

Ginseng reproduction is primarily sexual. Flowers are pollinated by insects. Seeds are dispersed by birds, mammals, and gravity. Generally, ginseng occurs in colonies formed from seeds falling in the immediate vicinity of parent plants. A thick, tuberous root develops after several years.

Commercial and private plant collecting and lumbering pose the greatest threats to this species.

Orono Sedge

Orono sedge, an endemic sedge found only in the Penobscot River valley, is another threatened species. Carex is a large genus of morphologically similar species which are grouped into sections. The Orono sedge is a member of the section Ovales, of which there are 19 species in Maine. The Orono sedge may be of hybrid origin (Gleason and Cronquist 1963) which would prevent its being listed as a threatened species.

The current distribution of this plant in coastal Maine is unknown. It is probably overlooked by most botanists, who tend to avoid collecting sedges. It was collected in Old Town, Orono, Bangor, Dedham, Frankfort, and Mattawamkeg between 1890 and 1916, and again (1978) in Old Town (personal communication from L. M. Eastman, botanist, Old Orchard Beach, ME.; August, 1978).

The Orono sedge is a wind-pollinated, tufted, perennial that grows in wet and dry fields, meadows, and clearings. It is often found in gravelly substrates. Over-grazing, mowing, and construction are the chief threats to this plant.

Long's Bitter Cress

Long's bitter cress is a small biennial or short-lived perennial mustard. According to herbarium specimens, Long's bitter cress grows only on muddy banks of tidal and nontidal estuaries and streams. It is most frequently reported in the freshwater area of tidal estuaries and not along the borders of salt marshes as stated by Gleason and Cronquist (1963). Four collections of this plant have been made in coastal Maine: two along the Cathance River in Bowdoinham (region 2), one in Ocean Point, Lincoln County (region 2), and one in Hancock County (regions 4 and 5; Crovello 1978). Unverified specimens of Long's bitter cress were collected at Pine Point in Phippsburg (region 2), and on Mt. Desert Island (region 5). It also has been collected in New Hampshire, Massachusetts (where it was introduced), Connecticut, New Jersey, Virginia, and the Carolinas (Crovello 1978).

Long's bitter cress, C. longii, looks very much like extreme forms of C. pensylvanica var. brittoniana Farw., which is not as rare in Maine. Whether C. Longii is a species has been questioned (personal communications from: H. E. Ahles, University of Massachusetts Herbarium, Amherst, MA., February, 1978; T. J. Crovello, University of Notre Dame, Notre Dame, IN., February, 1978; and L. M. Eastman, botanist, Old Orchard Beach, ME., February, 1978). It may be a form of C. pensylvanica, whose compound lower leaves drop off prematurely leaving only the simple cauline leaves found on all the collected specimens. Transplant experiments of C. longii and C. pensylvanica, followed by analysis of the critical characters of their fruits, pedicels, and flowers, would help evaluate the taxonomic status of this plant.

Eastman (1976b), Ahles (in preparation), and Crovello (1978) reviewed the distributional status of Long's bitter cress in Maine, New England, and North America, respectively. Fernald (1917 and 1941) and Fassett (1928) commented on its restricted distribution in Maine in the past. One station (occurrence) of the species was found in Maine in 1972, which was located again by Eastman and Delaney in 1976 (Eastman 1976b). This station is located along the Cathance River near the River Bend Camps in Bowdoinham (region 2), and has been designated a critical area by the Critical Areas Program of the Maine State Planning Office. Another station was located upriver in Topsham in 1979 by biologists from the Critical Areas Program.

The species was first described by Fernald (Eastman 1976b; and Crovello 1978) based on collections made at the River Bend Camps in 1916. Fasset collected the species from the Cathance River area in 1920, and from Centers Point, Bowdoinham, in 1921. Iltis and Patman, in 1959, and Crovello, in 1975 (Crovello 1978), changed a specimen labelled Cardamine pensylvanica Muhl. (which was originally collected from a small brook in Ocean Point, Lincoln County, and identified by Fasset in 1925) to Cardamine longii. A second specimen labelled Cardamine hirsuta L., which was collected in Hancock County, by E. L. Rand in 1890, was similarly changed to C. longii by Crovello (1978).

Little biological information on C. longii is available. Reproduction is sexual and the apetalous flowers are probably self-pollinated since mustard pollen is heavy and is not easily transported by wind. Seeds are borne in elastically dehiscing capsules (siliques). This method of dehiscence is found only in this genus (personal communication from H. E. Ahles, University of Massachusetts, Amherst, MA; November, 1979).

Stream channeling, hydroelectric dams, plant collecting, and competition from introduced weeds, are the major threats to this species.

RARE PLANTS

To date, 84 species of vascular plants in the coastal zone are considered rare in Maine (table 20-2; Eastman 1978a and b). Six of these are trees, 15 are shrubs, 58 are herbaceous dicots, 17 are herbaceous monocots, and 6 are lower vascular plants (ferns and club mosses). Six species are annuals, 3 are biennials, and 75 are perennials.

Of the 84 rare species, 28 are located near the southern edge of their ranges, 42 are located near the northern edge, and 14 are located near the center portion of their range. Many of the northern species are relict populations from the last glacial period (12,000 years ago), and many of the southern species are relict populations from the hypsithermal period (a warm period), which ended about 2500 years ago.

The habitats, or plant communities, where rare plants are found include: mature forest; sphagnum bogs, fens, and Atlantic or northern white cedar forested wetlands; wet meadows and alluvial thickets; estuarine emergent wetlands and estuarine shorelines; outer coastal headlands and islands; ledges and open ground; and non-sphagnous palustrine wetlands. Many of these plant communities are unique or rare. Associations of three or more rare plants occur in coastal plateau bogs, on outer headlands and islands, and in freshwater and brackish tidal marshes.

Locations where rare plants have been known to occur in coastal Maine are plotted on atlas map 4. Most locations are based on herbarium specimens which usually identify only the general location (i.e., a particular bog) and not the exact place of growth (i.e., location within the bog). The Critical Areas Program has additional data on the exact locations of species for which they have prepared critical area reports or botanical fact sheets, and species for which they are currently conducting inventories (see table 20-2).

UNIQUE OR RESTRICTED PLANT COMMUNITIES

There are several plant communities found along the Maine coast that have restricted distributions in Maine or the United States, or that support several rare plant species. These include coastal plateau bogs and shrub slope peatlands, some outer headland and coastal island plant communities, freshwater and brackish water intertidal emergent wetland communities, a forested wetland community dominated by Atlantic white cedar, and several sand beach and dune communities (sand beach and dune communities are discussed in chapter 4, "The Marine System").

Plant communities are composed of groups of species whose range of ecological requirements overlap. Individual species or groups of species are not restricted to particular plant species associations, rather each species is distributed along environmental gradients almost without regard to the occurrence of others. The more important ecological gradients influencing plant distribution in the coastal zone are atmospheric moisture (rainfall, runoff, and fog), soil and air temperature, evapotranspiration rate, substrate type (mineral vs. organic), nutrient availability, salinity (including salt spray), tidal regime, drainage, and others. These factors may act independently or interact to influence plant species distribution.

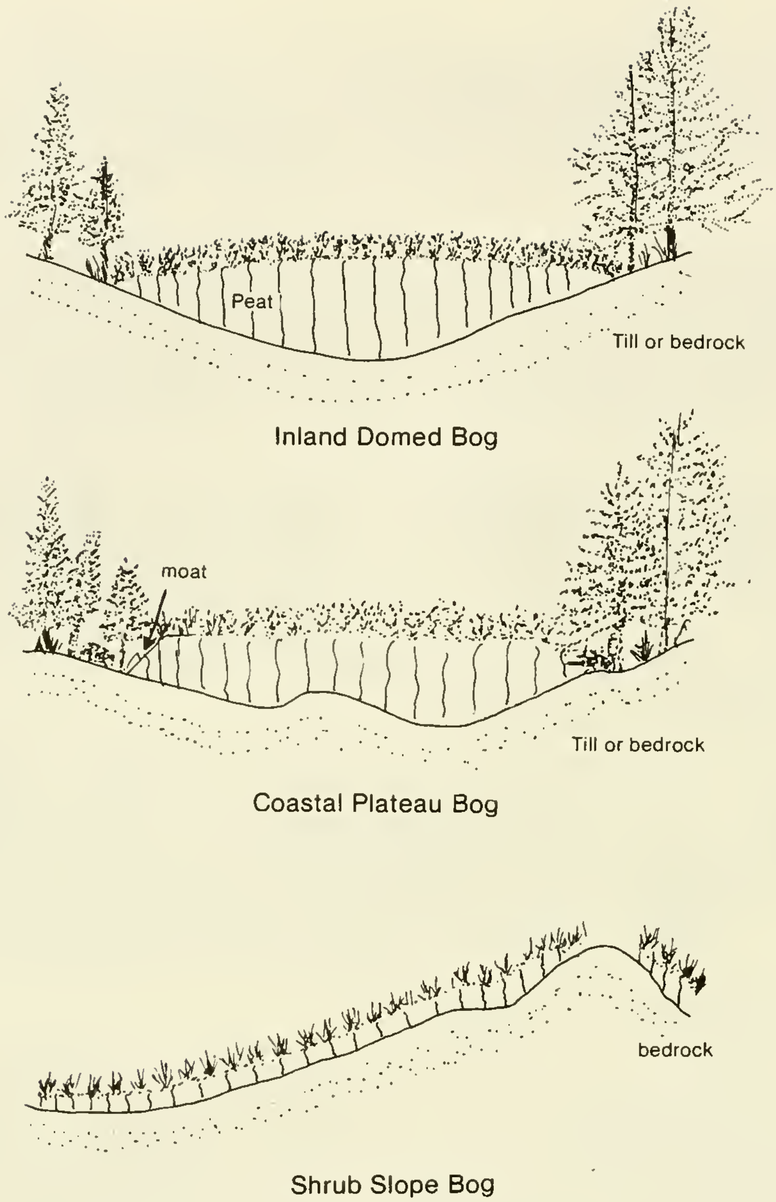

Figure 20-1 Comparison of the Three Types of Raised Bogs Found Along the Maine Coast (adapted from Damman 1979).

Coastal Plateau Bogs and Shrub Slope Peatlands

Coastal plateau bogs, or plateau peatlands, are a type of raised bog found primarily in eastern coastal Maine, usually within 6 miles (10 km) of open ocean. They differ from inland domed bogs, the more common type of raised bog found in coastal Maine, in surface topography and plant species composition. Plateau bogs have a pronounced slope which rises from a well-developed bog moat, or lagg, to an almost flat central bog plain (figure 20-1; Damman 1977). Inland domed bogs, such as the Great Heath in Cherryfield (region 5), are clearly domed with a gentle or gradual slope in all directions from the center, and the moat or lagg is usually lacking (figure 20-1). Plateau bogs and domed bogs correspond to Types 3 and 4, respectively, of Cameron's (1975) classification which is discussed and illustrated (figure 8-4) in chapter 8, "The Palustrine System."

A unique plant community dominated by black crowberry (Empetrum nigrum), Scirpus cespitosus, and baked apple berry (Rubus chamaemorus), is found on the flat central bog plain of plateau bogs. This community is very rare or absent from inland domed bogs but may occur on the tops of higher inland mountains. Several rare plant species occur in association with this plant community including baked apple berry, dragon's mouth (Arethusa bulbosa), a sedge (Carex rariflora), northern comandra (Geocaulon lividum), and possibly purple crowberry (Empetrum atropurpureum).

Coastal plateau bogs are found only along the Atlantic coast from eastern Maine to Labrador. These areas are characterized by a maritime climate with frequent summer fogs, cool temperatures (2.5 to 4°C; 4.5 to 7°F; less than nearby inland domed bogs; Damman 1977), high rainfall, high moisture input from fog drip (Davis 1966), and reduced evapotranspiration which results in a surplus of moisture during the growing season. The larger coastal plateau bogs are plotted on atlas map 4.

Shrub slope peatlands have been described only recently (Worley 1980b). They generally are associated with plateau peatlands, but are more restricted in distribution, being found only within a few km of open ocean (principally in region 6). Shrub slope peatlands have a dense cover of ericaceous shrubs, such as sheep laurel (Kalmia angustifolia) and leather leaf (Chamaedaphne calyculata). Black crowberry, baked apple berry, and Sphagnum spp. are also present. The dense vegetation covers a layer of peat some 4 to 16 inches (10 to 40 cm) thick that lies over undulating bedrock with slopes of at least 13° (figure 20-1; Worley 1980b). Shrub slope peatlands occupy terrain with "the most exposed, rainy, foggy, cool, temperate, maritime climate on the Maine coast" (Worley 1980b:31). The best examples are found on the southern end of Great Wass Island.

Outer Headlands and Outer Island Communities

Plant communities occupying exposed outer headlands and outer islands support rare plant species with northern affinities. These communities occupy the area between the exposed shoreline and the coastal spruce-fir stands, and are characterized by a dense shrub and herbaceous ground cover. Plant species that commonly occur in these communities are sheep laurel, ground juniper (Juniperus horizontalis), mountain cranberry (Vaccinium vitis-idae), black crowberry, three-tooth edcinquefoil (Potentilla tridentata), seaside plantain (Plantago juncoides), and various grasses.

The rare plant species found in this community are able to survive because of the cooler temperatures found along the coast. Many also are found inland at higher elevations (above 500 to 800 m) where temperatures are comparable to those along the immediate coast. Examples of some of the rare species found in these communities are beachhead iris (Iris hookeri), blinks (Montia lamposperma), mountain sandwort (Arenaria groenlandica), roseroot (Sedum rosea), purple crowberry, bird's-eye primrose (Primula laurentiana), marsh felwort (Lomatogonium rotatum), goldenrod (Solidago lepida), and yarrow (Achillea borealis). Iris, sandwort, roseroot, and primrose are often found together on the exposed ledges of coastal headlands in regions 5 and 6, and on outer islands in regions 3 through 6. The Great Wass Island archipelago in region 6, Little Moose Island near Schoodic penninsula in region 5, Isle au Haut in region 4, and Matinicus Isle and Matinicus Rock in region 3 support important associations of the above rare species.

A plant community dominated by jack pine (Pinus banksiana) is found in several areas on Mt. Desert Island, and the Schoodic and Corea peninsulas in region 5, and on Great Wass Island (region 6).

Freshwater Intertidal Emergent Wetlands

Freshwater intertidal emergent wetlands are relatively uncommon along the east coast of the United States. Large expanses of undisturbed freshwater intertidal emergent wetlands occur in Merrymeeting Bay in region 2, and lesser amounts occur in the Penobscot River estuary (region 4). Several rare plant species and named ecotypic varieties of more widely distributed species occupy these habitats, including Long's bitter cress, estuary monkey flower, and pipewort (Eriocaulon parkerii). This association is most abundant along the Cathance River in Topsham and Bowdoinham (region 2) and other localities in Merrymeeting Bay, and in the Reed Brook estuary (a tributary of the Penobscot River, region 4).

Brackish Intertidal Emergent Wetlands

An association of rare plant species is found locally in brackish intertidal emergent wetlands dominated by cordgrass (Spartina patens). These species are generally found in the upper portions of estuaries, especially the Sheepscot River, Sasonoa River, and Back River in region 2, and the Marsh River in region 4. Important rare plants occupying these habitats include a bulrush (Scirpus cylindricus), horned pondweed (Zannichellia palustris), water pimpernel (Samolus parviflorus), spike-rush (Eleocharis rostellata), and pipewort (Lilaeopsis chinensis).

Atlantic White Cedar Forested Wetlands

There is one forested wetland in the characterization area dominated by Atlantic white cedar (as opposed to northern white cedar which is very common). It is located in the town of Northport (region 4) and is registered as a critical area. This wetland is also dominated by sphagnum mosses. This community is the northernmost Atlantic white cedar wetland in Maine, although there are several others found in Maine south of the characterization area, and they are abundant in the coastal plain of the southeastern United States. In addition to Atlantic white cedar, dragon's mouth is the other rare plant species associated with this community.

FACTORS OF ABUNDANCE

The distribution and abundance of plant species are the result of natural and human-related factors. Long-term changes in climate and land forms (i.e., glaciation and mountain emergence) have resulted in the development of new species (speciation), the loss of species (extinction), and changes in distribution of species. Speciation and extinction are usually long, slow processes. People accelerated the extinction process in the last century by altering the earth's surface with advanced technology (Ayensu and DeFilipps 1978).

Some plant species are naturally rare, and have evolved adaptations to permit existence under conditions of low abundance. Many orchids, for example, have highly specific and "faithful" pollinators that allow them to exist in scattered populations. In addition, each plant produces large numbers of small seeds, a practice beneficial to less dense populations. Among species less-specialized than orchids, rarity is the result of a species' inability to adapt to change in habitat, climate, predator pressure, or competition.

Biotic factors affecting the distribution and abundance of plants include competition with newly-evolved or formerly allopatric (species whose ranges do not overlap) species, disease, damage from overgrazing by animals, insect damage, loss of pollinators, destruction of seeds and fruit, and changes in the soil-water regime (i.e., changes in drainage patterns, water table level, and waterholding capacity of the soil).

Plant populations have been reduced severely by human activities such as real estate developing, impounding water, and lowering the water table by wells, drainage, and peat mining. Populations of ginseng have been eradicated by commercial plant collectors along with mountain laurel and rhododendron. Orchids, and other aesthetically attractive plants, are subject to private plant collecting.

Timber removal, particularly clearcutting, directly alters plant habitats. Clearcutting results in changes in the light regime of the understory, the shrub and herbaceous layers, mechanical damage to the residual vegetation, changes in evapotranspiration rates, and increased erosion and nutrient depletion of the soil. The site preparation procedures most commonly used in coastal Maine are bulldozing, burning, and herbicidal application, which destroy the residual vegetation. Timber removal is likely to affect rare forest-dwelling species.

Introduced vascular plants sometimes reproduce prolifically and compete more successfully for light and space than native species. Introduced species are usually free of native diseases and pests, which, if present, keep them in biological balance. Many introduced species are vigorous, aggressive weeds. Approximately 24% of Maine's flora is composed of naturalized exotics and garden escapees. The degree of competition between introduced plants and rare species in coastal Maine is unknown.

The direct and indirect ways in which plants and plant habitats in the United States are threatened by human activities are summarized by Ayensu and DeFilipps (1978). The following apply to coastal Maine:

- Forestry practices: clearcutting; herbicides; replacing native trees with exotic timber trees.
- Biocide spraying: insecticides; herbicides.
- Mining: peat mining; subsurface mining.
- Real estate development and construction: roads; housing tracts; landclearing; power plants; shopping centers; golf courses; landscaping.
- Over grazing: by domesticated or feral goats, sheep, cattle, deer, pigs, rabbits, with associated trampling; (this is the greatest potential problem on coastal islands).
- Introduction of competitive weeds: chokers of native vegetation.
- Fire: destructive fires; preventing natural fires.
- Agriculture: fields cleared of vegetation for monoculture crops.
- Water management: flooding; stream channeling; tidal power; hydroelectric dams; drainage of swamps.
- Illegal removal of rare plants: from Federal, State and private land.
- Commercial exploitation: potential for most rare plants.
- Collecting by private individuals: for transplanting to gardens.
- Trampling of vegetation by people: inviting accelerated soil erosion, and destruction of fragile ecosystems, such as bogs and fens.

PROTECTION OF ENDANGERED, THREATENED, AND RARE PLANT SPECIES

The Endangered Species Act of 1973 places legal restrictions on the exploitation, propagation, use, and destruction of endangered and threatened species (or parts derived from them) or their habitats. For example, interstate and international commerce of threatened and endangered plants is illegal. Federal permits are required to propagate or enhance the survival of these species and for their use in scientific study. Plans for developments requiring Federal approval (e.g., highways, dams, stream alteration) must include consideration of endangered and threatened species.

The Endangered Species Act also mandates the responsibility of maintaining lists of plants and animals throughout the world judged by the Secretary of the Interior to be in danger of extinction or likely to become so. Once a plant species, subspecies, or variety is determined by the FWS to be endangered or threatened its name is placed on an official list published in the Federal Register. The estuary monkey flower is the only coastal Maine variety whose name has appeared on this list. After a plant has been listed, habitats critical to its survival must be identified and public hearings may be held for discussion of its status. Critical habitats must be named within one year of listing or the plant will be removed from the list. On 10 November 1979 all plants listed as endangered or threatened in coastal Maine were removed from the official list because critical habitats were not named. Any species can be relisted at any time. FWS biologists give priority to complete species (rather than subspecies) and species whose taxonomic status is generally agreed upon by taonomists.

Rare plant species do not receive protection under the Endangered Species Act. The locations where rare plants are found may be designated critical areas by the Critical Areas Program. Through the efforts of the Critical Areas Program some rare plant stations have been protected through the cooperation of the landowner (Tyler and Gowler 1980). The Critical Areas Program, working closely with the Nature Conservency and Maine Coast Heritage Trust, has helped acquire (i.e., Great Wass Island in region 6), or gain conservation easements on (i.e., Seawall Beach in region 2), several rare plant locations or unusual rare plant communities.

MANAGEMENT

The management of endangered plant species is regulated by the Department of the Interior. Currently no plant species in the coastal zone are under Federal protection because critical habitat was not described within the one year following listing. However, species on the original list (Mimulus ringens var. colpophilus), species listed in the Smithsonian report, and most species on the Maine rare plant list are in need of protection.

The Smithsonian report (Ayensu and DeFilipps 1978) summarized the key elements of endangered species management:

1. Prevention of the destruction of populations and their habitats.
2. Monitoring and research on population levels and viability.
3. Prevention of collection and commercial exploitation.

This report states that the preservation and protection of habitats upon which the plants depend for growth and reproduction are the foremost needs in rare plant management. It further states that in situ perpetuation of sufficient populations of endangered and threatened plants is required to ensure their survival.

Various methods of protection and preserving habitats and populations include landmark designations, conservation easements, tax breaks for landowners, acquisition, and penalty procedures. Priority should be given to habitats supporting more than one species.

Endangered, threatened, and rare plants should be recognized as basic elements in land-use plans and inventories in which the Federal Government is involved either in a direct capacity or in the role of a guiding or advisory party. Federal agencies involved in land management, including the Bureau of Land Management, Fish and Wildlife Service, Department of Energy, Army Corps of Engineers, National Park Service, Forest Service, Energy Research and Development Administration, Department of Defense, Soil Conservation Service, and U.S. Geological Survey, should recognize endangered, threatened, and rare species as natural resources and consider their distribution in natural resource surveys and inventories.

RESEARCH NEEDS

Little is known about the current population status of endangered, threatened, and rare plant species in the coastal zone. More information is needed to evaluate potential threats from human activities and to help guide protective and management procedures.

The taxonomic validity or invalidity of *Carex oronensis*, *Cardamine longii*, and *Mimulus ringens* var. *colpophilus* needs to be established so protective measures may be implemented on the valid species or varieties.

Information on important 'life history' characteristics of endangered and threatened species would help guide management decisions affecting these species.

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