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The Wetlands of Acadia National Park and Vicinity

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Maine Agricultural and Forest Experiment Station
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Technical Report Prepared by

Aram J.K. Calhoun
Department of Plant Biology and Pathology
University of Maine, Orono, ME 04469

Janet E. Cormier
Soil Consulting Services
Box 11, Monson, ME 04464

Ray B. Owen Jr.
Department of Wildlife Ecology
University of Maine, Orono, ME 04469

Allan F. O'Connell Jr.
National Park Service, Cooperative Park Studies Unit
University of Maine, Orono, ME 04469

Charles T. Roman
National Park Service, Cooperative Park Studies Unit
University of Rhode Island, Narragansett, RI 02882

Ralph W. Tiner Jr.
U.S. Fish and Wildlife Service, National Wetlands Inventory
300 Westgate Center Dr., Hadley, MA 01035

National Wetland Inventory Maps Prepared by

Ralph W. Tiner Jr. and Glenn Smith
U.S. Fish and Wildlife Service, National Wetlands Inventory
Hadley, MA 01035

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Contents

FIGURES v
PLATES vi
TABLES vi
EXECUTIVE SUMMARY vii
ACKNOWLEDGMENTS viii

CHAPTER 1. INTRODUCTION 1
- Introduction 1
- Description of the Study Area 1
- Purpose and Organization of This Report 1
- Literature Cited 3

CHAPTER 2. U.S. FISH AND WILDLIFE SERVICE'S WETLAND DEFINITION AND CLASSIFICATION SYSTEM 4
- Introduction 4
- Wetland Definition 4
- Wetland Classification 7
- Literature Cited 11

CHAPTER 3. NATIONAL WETLANDS INVENTORY MAPPING TECHNIQUES AND RESULTS 12
- Introduction 12
- Wetlands Inventory Techniques 12
- Results 13
- Summary 17
- Literature Cited 17

CHAPTER 4. WETLAND FORMATION AND HYDROLOGY IN THE ACADIA REGION 20
- Introduction 20
- Geologic History 20
- Freshwater Wetland Formation 22
- Tidal Wetland Formation 24
- Wetland Hydrology 28
- Literature Cited 31

CHAPTER 5. THE HYDRIC SOILS OF ACADIA NATIONAL PARK AND VICINITY 33
- Introduction 33
- Definition of Hydric Soil 33
- Hydric Soil Characteristics 33
- Hydric Soils in the Landscape 35
- Hydric Soil Descriptions 35

Hydric Soils on the Islands 39
Literature Cited 40

CHAPTER 6. WETLAND PLANT COMMUNITIES 45
Introduction 45
Wetland Communities 45
Literature Cited 73

CHAPTER 7. WETLAND VALUES 75
Introduction 75
Physical Environment 75
Biological Values 78
Human Values 82
Literature Cited 83

CHAPTER 8. WETLAND FAUNA OF ACADIA NATIONAL PARK AND VICINITY 85
Waterfowl and Other Birds 85
Mammals, Reptiles and Amphibians 86
Fish and Invertebrates 87
Literature Cited 91

CHAPTER 9. WETLAND PROTECTION 92
Introduction 92
Wetland Regulations 92
Wetland Acquisition 97
Future Actions 97
Literature Cited 99

APPENDIX 1. DETAILED SOIL DESCRIPTIONS 100

APPENDIX 2. PLANT SPECIES OBSERVED IN THE ACADIA REGION'S WETLANDS 104

APPENDIX 3. SIGNIFICANT LAKES AND PONDS OF ACADIA NATIONAL PARK 106

Figures

1. Map of the Acadia region, Schoodic Peninsula to Isle au Haut 2
2. Diagram showing major wetland and deepwater habitat systems 5
3. Classification hierarchy of wetlands and deepwater habitats showing systems, subsystems, and classes 8
4. National Wetlands Inventory map depicting wetlands in the vicinity of Big Heath, Acadia National Park, Mount Desert Island, Maine. 14
5. Number of wetland units by system in Acadia National Park and vicinity 16
6. Distribution of palustrine wetlands by size class in Acadia National Park and vicinity 16
7. Distribution of hydric soils on Mount Desert Island 17
8. Distribution of the five wetland systems in Acadia National Park. 19
9. Glacial landscape forming Jordan Pond 21

10a. Mount Desert Island during deglaciation. Ice tongues linger in the valley, while the ridges are ice free 22

10b. U-shaped valley at the south end of the Tarn. 23

11. Coastal compartments of the Maine coast based on variation in rock composition and structure ... 25
12. Maine salt marsh geomorphology 26
13. Hydrology of coastal wetlands showing different zones of flooding 27
14. Hydrology of surface (A & B) and groundwater (C & D) wetlands (Tiner 1989). 29
15. Idealized cross section of the Acadian landscape and the positions of hydric soils 36
16. Distinguishing features and examples of habitats in the Marine System 48
17. Distinguishing features and examples of habitats in the Estuarine System 49
18. Generalized plant zonation in southern New England salt marshes: (1) low marsh and (2) high marsh 52
19. Distinguishing features and examples of habitats in the Riverine System 55
20. Distinguishing features and examples of habitats in the Lacustrine System 56
21. Distinguishing features and examples of habitats in the Palustrine System. 58
22. Eastern North American distribution of coastal plateau peatlands, *Scirpus* lawn communities, and the phenomenon of minerotrophic species on ombrotrophic peats. 65
23. Vegetation pattern in the three major raised bog types of northern New England 66
24. Mount Desert Island showing areas burned in 1947 68
25. David Hunter Struther, The Barge 75
26. Wetlands help reduce flood crests and slow flow rates after rainstorms 77
27. Simplified food pathways from estuarine vegetation to commercially and recreationally important fishes and shellfishes. 82
28. Food chain relationships in an aquatic ecosystem 89

Plates

1. Marine aquatic bed. Note algal zonation related to tidal exposure. 41
2. An example of a wetland complex including Marine, Estuarine, and Palustrine systems at Sand Beach, ANP. 41
3. Salt marsh at Bass Harbor. An estuarine emergent wetland exhibiting high primary production and providing nursery areas for a diversity of marine organisms. 42
4. Beaver meadow near Witchhole Pond. An example of a palustrine emergent wetland resulting from inundation of a forested wetland by beaver. 42
5. An example of a palustrine scrub-shrub wetland dominated by leatherleaf. 43
6. Big Heath, ANP. An example of a rare peatland type, a raised coastal plateau bog. 43
7. An example of a poorly drained hydric soil (Westbury) in the Blackwoods area, ANP. 44
8. *Arethusa bulbosa*, a rare orchid found in peatlands. 44
9. Northeast Creek, a riverine wetland complex including submerged aquatic beds as well as adjacent palustrine wetlands. 44
10. An example of a marine intertidal unconsolidated shore on Isle au Haut. 44

Tables

1. Classes and subclasses of wetlands and deepwater habitats (Cowardin et al. 1979). 6
2. Water regime modifiers, both tidal and nontidal groups (Cowardin et al. 1979). 7
3. Salinity modifiers for coastal and inland areas (Cowardin et al. 1979) 10
4. Wetland area summaries and percentages of wetland area for Acadia National Park and vicinity. 15
5. Area (ha) of hydric soils within wetland systems in Acadia National Park and vicinity. 15
6. Wetland area and frequency summaries by township for Acadia National Park and vicinity 18
7. Tidal ranges on Mount Desert Island and vicinity. 27
8. Examples of plant indicators of tidal water regimes for the Acadia region's estuarine wetlands 27
9. Examples of plant indicators of water regimes for the Acadia region's nontidal wetlands 28
10. Definitions of soil drainage classes. 34
11. Hydric soil chart: Relationships of parent material, drainage class, soil series and classification. 37
12. Characteristic wetland plant communities in Acadia National Park and vicinity. 46
13. Significant features of lakes and ponds in Acadia National Park and vicinity. 57
14. Rare wetland plants of Acadia National Park. 72
15. List of major wetland values. 76
16. Animals considered rare or whose status is unknown who are at least partially dependent on wetlands and may occur in Acadia National Park and vicinity 79
17. Peatlands as significant natural features 80
18. Significance of Coastal Plateau Bogs of Maine 80
19. Average mid-winter waterfowl inventories for Frenchman and Blue Hill bays. 86
20. Functional groups of aquatic insects, their foods and feeding mechanisms 90
21. Summary of primary federal and state laws relating to wetland protection in Maine. 94
22. Highlights of wetlands guidance outlined in the floodplain management and wetlands protection guidelines. 96

EXECUTIVE SUMMARY

The purpose of this report is to describe the wetlands of Acadia National Park and vicinity. The formation of the region's wetlands is discussed, along with detailed descriptions of wetland soils, hydrology, vegetation, utilization by fauna, as well as wetlands' many ecological and cultural values. Moreover, based on maps produced by the U.S. Fish and Wildlife Service's National Wetlands Inventory, statistics on the area and distribution of wetlands within the study area are provided. Wetlands encompass 12,847 hectares, or 20%, of the Acadia region study area. The majority of wetlands are classified as marine (38% of the total wetland area) and palustrine (32%). The Marine System is dominated by algal beds of the rocky shoreline, while forested wetlands, bogs, and fens dominate the Palustrine System. Wetlands of the Estuarine System (e.g., slat marshes, sand and mud flats) and Lacustrine System, including the region's many lakes, ponds, and associated littoral habitats, encompassed 20% and 11%, respectively, of the study area's total wetland area. Only 0.2% of the region's wetland habitat was classified as riverine. The report closes with a discussion of wetland protection techniques and recommendations to the National Park Service for maintenance and enhancement of wetland functions and values.

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Credits

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CHAPTER 1. INTRODUCTION

INTRODUCTION

Although the wetlands of Acadia National Park (ANP) and vicinity encompass only 20% of the land area, they greatly enhance the natural beauty and biological richness of the region. Because of its diverse topography and coastal setting, the Acadia region encompasses a variety of ecological landscapes, from alpine communities and coniferous forests to rare coastal plateau bogs, salt marshes, and ephemeral pools in forested wetlands. Wetlands have many unique traits of ecological, economic, and recreational value. A major goal of this report is to illustrate the wonderful diversity of wetlands in the Acadia region as well as their values and significance.

Assessments of wetland resources are the traditional responsibilities of the U.S. Fish and Wildlife Service (USFWS). In 1974, the USFWS initiated a broad-based inventory, the National Wetlands Inventory (NWI), which resulted in the development of a wetland classification scheme for the United States (Cowardin et al. 1979). Based on this classification scheme, wetland maps were prepared and are currently available for 61% of the area of the lower 48 states, including approximately 75% of Maine. In addition, companion NWI technical reports for individual states and status and trends reports have been compiled to provide resource professionals with up-to-date information on wetland distribution and classification (e.g., forested, scrub-shrub, aquatic bed). Such periodic reports of the status of wetlands, including statistics on wetland losses and gains, are needed to assess the effectiveness of protection programs and regulatory policies and to provide the public with current information. The present report on the wetlands of the Acadia region meets these needs.

DESCRIPTION OF THE STUDY AREA

The Acadia region is located along Maine's mid-coast (44° 12' – 44° 27' N., 68° 19' – 68° 27' W.) and includes Mount Desert Island (MDI), Schoodic Peninsula, Isle au Haut, Swans Island, the Cranberry Isles, and numerous other smaller coastal islands in the Penobscot/Frenchman Bay region (Figure 1).

It lies at the southern limit of the spruce-fir northern hardwoods zone (Westveld et al. 1956). The landscape is relatively rugged, distinguished by the highest topographic point along the coast of the eastern United States, Cadillac Mountain (500 meters), and the only fjord in eastern North America, Somes Sound. MDI is characterized by north-south trending mountains separated by U-shaped valleys (Patterson et al. 1983) and over 30 freshwater lakes and ponds (National Park Service 1991). The smaller islands have less dramatic topography. Upland areas are characterized by thin, granitic soils (Gilman et al. 1988; Chapman 1970) while organic soils are extensive in wetland areas. Watersheds are typically short in length (<5 kilometers from headwaters to the sea). Consequently, large rivers are absent, although numerous streams and brooks drain into the ocean.

The cool, humid climate of the region is heavily influenced by its marine setting and latitude. Annual precipitation between 1982 and 1989 averaged 139 centimeters (NOAA 1980–1989). Mean seasonal temperatures between 1980 and 1989 ranged between -6.8°C for winter and 18.3°C for summer (NOAA 1980–1989).

PURPOSE AND ORGANIZATION OF THIS REPORT

Many of Maine's wetlands (including those in ANP) were inventoried and mapped by NWI using aerial photography flown in the 1970s. A number of factors, including landscape changes with time, availability of higher resolution photography, and the 1986 legislation of a boundary for ANP, supported updating the wetland inventory. The new inventory will be a useful tool for resource protection managers, landuse planners, educators, and researchers. It extends beyond ANP boundaries to permit a watershed approach to wetland assessment and protection. Because political boundaries rarely conform to watershed boundaries, cooperative efforts between the National Park Service (NPS) and local towns are needed to ensure the future protection of wetland resources.

More specifically, this report gives an overview of the Acadia region's wetlands—their formation, soils, characteristic flora and fauna, values, and policies affecting their regulation. The format of this document follows that of NWI state wetland reports (Tiner 1989; Metzler and Tiner 1992). Individual chapters include a discussion of wetland definitions and classification (Chapter 2), NWI techniques and results (Chapter 3), wetland formation and hydrology (Chapter 4), hydric soils (Chapter 5), wetland vegetation and plant com-

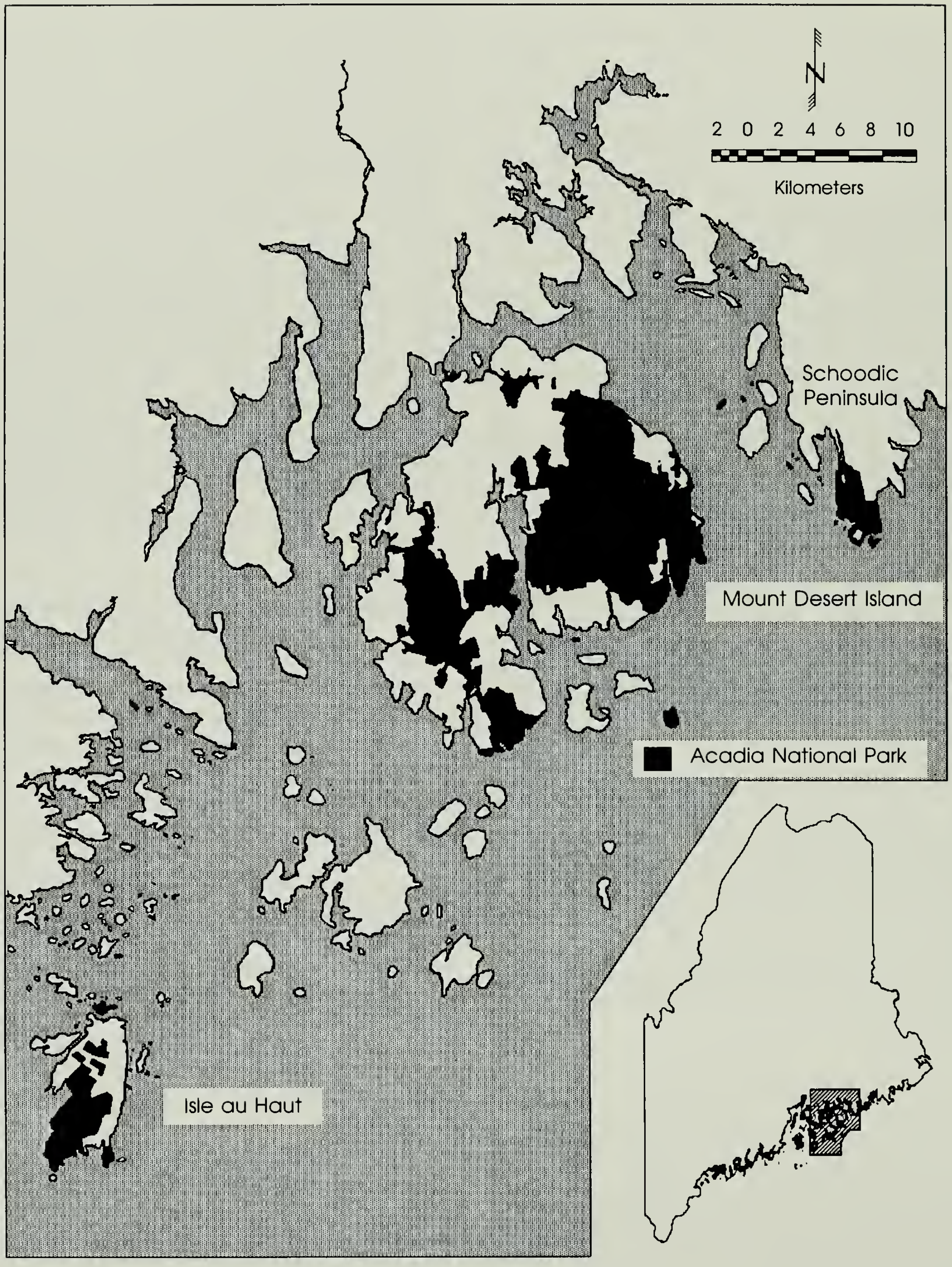

Figure 1. Map of the Acadia region, Schoodic Peninsula to Isle au Haut, including Mount Desert Island and Acadia National Park.

munities (Chapter 6), wetland values (Chapter 7), wetland fauna (Chapter 8), and wetland protection (Chapter 9). Scientific names of vascular plants identified in the region's wetlands during the two-year field survey are found in Appendix 2.

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CHAPTER 2. U.S. FISH AND WILDLIFE SERVICE'S WETLAND DEFINITION AND CLASSIFICATION SYSTEM

INTRODUCTION

The wetlands of Acadia were inventoried and classified according to the USFWS wetland classification system entitled *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979). Four key objectives for this national system were established: (1) to develop ecologically similar habitat units, (2) to arrange these units in a system that would facilitate resource management decisions, (3) to furnish units for inventory and mapping, and (4) to provide uniformity in concept and terminology throughout the United States. The classification system went through three major drafts and extensive field testing and review by numerous state and federal agencies, university scientists, and others prior to its final publication.

Since its publication, the classification system has been widely used by federal, state, and local agencies, university scientists, and private industry and non-profit organizations for classifying and mapping wetlands. Thus, it appears to be moving quickly towards its goal of providing uniformity in wetland concept and terminology.

WETLAND DEFINITION

Conceptually, wetlands usually lie between the better-drained, rarely flooded uplands and the permanently flooded deep waters of lakes, rivers, and coastal embayments (Figure 2). Wetlands include the variety of marshes, bogs, swamps, shallow ponds, and bottomland forests found throughout the country. They usually occur in upland depressions, or along rivers, lakes, and coastal waters where they are subject to periodic flooding or saturation to the surface due to high water tables. Some wetlands, however, occur on slopes where they are associated with groundwater seepage areas.

To accurately inventory this resource, the USFWS had to determine where along this natural wetness continuum wetland ends and upland begins. While many wetlands lie in distinct depressions or basins that are readily observable, the wetland-upland boundary is not always easy to identify. This is especially true along many floodplains, on glacial till deposits, in gently sloping terrain, and in areas of major hydrologic modification. In these areas, only a skilled wetland ecologist or other specialist can accurately identify the wetland boundary. To help ensure accurate and consistent wetland determination, an ecologically based definition was constructed by the USFWS.

For purposes of the National Wetlands Inventory, USFWS defines wetlands as follows:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979:3).

In developing this multidisciplinary definition of wetland, the USFWS first acknowledged that "there is no single, correct, indisputable, ecologically sound definition for wetlands, primarily because of the diversity of wetlands and because the demarcation between dry and wet environments lies along a continuum" (Cowardin et al. 1979:3). After all, a wealth of wetland definitions grew out of different needs for defining wetlands among various groups or organizations, i.e., wetland regulators, waterfowl managers, hydrologists, flood control engineers, and water quality experts. The USFWS had not attempted to legally define wetland since prior to 1989 the four federal agencies involved in wetland jurisdiction (Environmental Protection Agency [EPA], Soil Conservation Service [SCS], Army Corps of Engineers [Corps], and USFWS) each defined wetlands differently to suit administrative needs. This compounded the confusion already felt by regulators and the public as wetland definitions also vary from state to state. In a step towards greater coordination of federal determinations, greater consistency in policy, and more accurate delineation and identification of the nation's wetlands for resource management purposes, the four agencies agreed to a common definition as set forth in the 1989 Federal Manual for Delineation of Jurisdictional Wetlands (Federal Interagency Committee on Wetland Delineation 1989). This manual, however, met with a great deal of controversy because many felt that it arbitrarily expanded the area of jurisdictional wetlands. However, revisions promulgated in 1991 were rejected for greatly dimin-

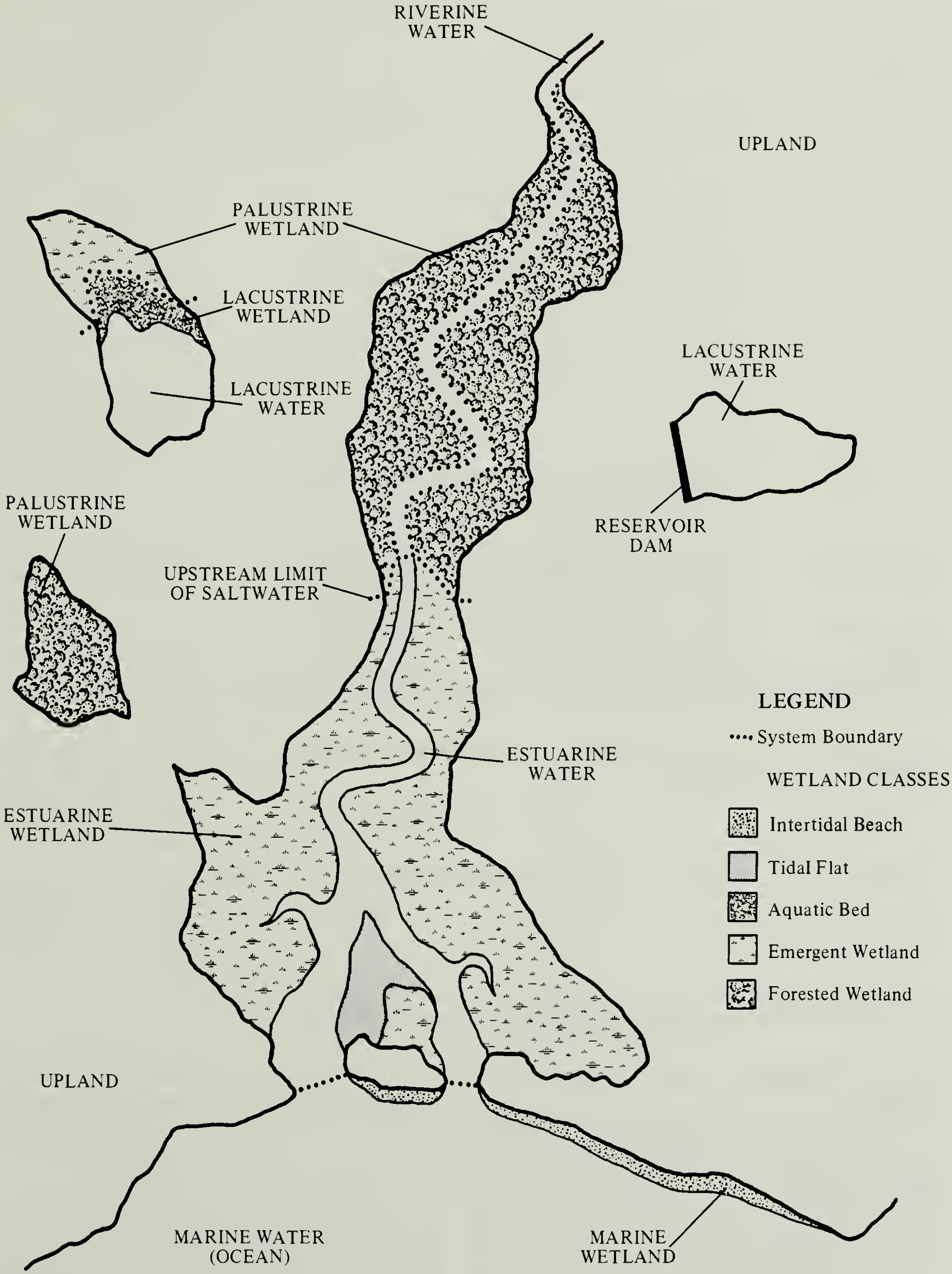

Figure 2. Diagram showing major wetland and deepwater habitat systems. Predominant wetland classes for each system are also designated. (Note: Tidal flat and beach classes are now considered unconsolidated shore.) (Tiner 1989)

Table 1. Classes and subclasses of wetlands and deepwater habitats (Cowardin et al. 1979).

Class	Brief Description	Subclasses
Rock Bottom	Generally permanently flooded areas with bottom substrates consisting of at least 75% stones and boulders and less than 30% vegetative cover.	Bedrock; Rubble.
Unconsolidated Bottom	Generally permanently flooded areas with bottom substrates consisting of at least 25% particles smaller than stones and less than 30% vegetative cover.	Cobble-gravel; Sand; Mud; Organic
Aquatic Bed	Generally permanently flooded areas vegetated by plants growing principally on or below the water surface line.	Algal; Aquatic Moss; Rooted Vascular; Floating Vascular
Reef	Ridge-like or mound-like structures formed by the colonization and growth of sedentary invertebrates.	Coral; Mollusk; Worm
Streambed	Channel whose bottom is completely dewatered at low water periods.	Bedrock; Rubble; Cobble-gravel; Sand; Mud; Organic; Vegetated
Rocky Shore	Wetlands characterized by bedrock, stones, or boulders with areal coverage of 75% or more and with less than 30% coverage by vegetation.	Bedrock; Rubble
Unconsolidated Shore*	Wetlands having unconsolidated substrates with less than 75% coverage by stone, boulders and bedrock and less than 30% vegetative cover, except by pioneer plants.	Cobble-gravel; Sand; Mud; Organic; Vegetated
Moss-Lichen Wetland	Wetlands dominated by mosses or lichens where other plants have less than 30% coverage.	Moss; Lichen
Emergent Wetland	Wetlands dominated by erect, rooted, herbaceous hydrophytes.	Persistent; Nonpersistent
Scrub-Shrub Wetland	Wetlands dominated by woody vegetation less than 20 feet (6 m) tall	Broad-leaved Deciduous; Needle-leaved Deciduous; Broad-leaved Evergreen; Needle-leaved Evergreen; Dead
Forested Wetland	Wetlands dominated by wood vegetation 20 feet (6 m) or taller.	Broad-leaved Deciduous; Needle-leaved Deciduous; Broad-leaved Evergreen; Needle-leaved Evergreen; Dead

*NOTE: This class combines two classes of the 1977 operational draft system—Beach/Bar and Flat)

ishing the geographical extent of jurisdictional wetlands.

In an attempt to resolve this controversy, Congress directed the EPA to fund a National Academy of Science (NAS) study of wetland delineation. The study is expected to be completed by fall of 1994. Since January of 1993, federal agencies have adopted a manual developed by the Corps in 1987 (Environmental Laboratories 1987). The Clinton administration supports the use of the 1987 Manual by the Corps, EPA, SCS, and USFWS pending the NAS study (White House Office on Environmental Policy 1993).

In defining wetlands from an ecological standpoint, the federal agencies use a three-parameter approach: (1) hydrology—the degree of flooding or soil saturation, (2) wetland vegetation (hydrophytes), and (3) hydric soils. All areas considered wetland must have enough water at some time during the growing season to stress plants and animals not adapted for life in water or saturated soils. Most wetlands have hydrophytes and hydric soils present, yet many are nonvegetated (e.g., tidal mudflats). To aid in wetland identification, the USFWS has prepared a list of plants occurring in the nation's wetlands (Reed 1988), and the SCS

Table 2. Water regime modifiers, both tidal and nontidal groups (Cowardin et al. 1979).

Group	Type of Water	Water Regime	Definition
Tidal	Saltwater and brackish areas	Subtidal	Permanently flooded tidal waters
		Irregularly exposed	Exposed less often than daily by tides
		Regularly flooded	Daily tidal flooding and exposure to air
		Irregularly flooded	Flooded less often than daily and typically exposed to air
	Freshwater	Permanently flooded-tidal	Permanently flooded by tides and river or exposed irregularly by tides
		Semipermanently flooded-tidal	Flooded for most of the growing season by river overflow but tidal fluctuation in water levels
		Regularly flooded	Daily tidal flooding and exposure to air
		Seasonally flooded-tidal	Flooded irregularly by tides and seasonally by river overflow
		Temporarily flooded-tidal	Flooded irregularly by tides and for brief periods during growing season by river overflow
Nontidal	Inland freshwater	Permanently flooded	Flooded throughout the year in all years and saline areas
		Intermittently exposed	Flooded year-round except during extreme droughts
		Semipermanently flooded	Flooded throughout the growing season in most years
		Seasonally flooded	Flooded for extended periods in growing season, but surface water is usually absent by end of growing season
		Saturated	Surface water is seldom present, but substrate is saturated to the surface for most of the season
		Temporarily flooded	Flooded for only brief periods during growing season, with water table usually well below the soil surface for most of the season
		Intermittently flooded	Substrate is usually exposed and only flooded for variable periods without detectable seasonal periodicity (Not always wetland: may be upland in some situations)
		Artificially flooded	Duration and amount of flooding is controlled by means of pumps or siphons in combination with dikes or dams

has developed a national list of hydric soils (USDA Soil Conservation Service 1991).

WETLAND CLASSIFICATION

The following section represents a simplified overview of the USFWS's wetland classification system. Consequently, some of the more technical points have been omitted from this discussion. When actually classifying a wetland, the reader is advised to refer to the official classification document (Cowardin et al. 1979) and should not rely solely on this overview.

Wetlands typically fall within one of the following four categories: (1) areas with both hydrophytes and hydric soils (e.g., marshes, swamps, and bogs); (2) areas without hydrophytes, but with hydric soils (e.g., farmed wetlands); (3) areas without soils, but with hydrophytes (e.g., seaweed-covered rocky shores); and (4) periodically flooded areas without soil and without hydrophytes (e.g., gravel beaches). All wetlands must be periodically

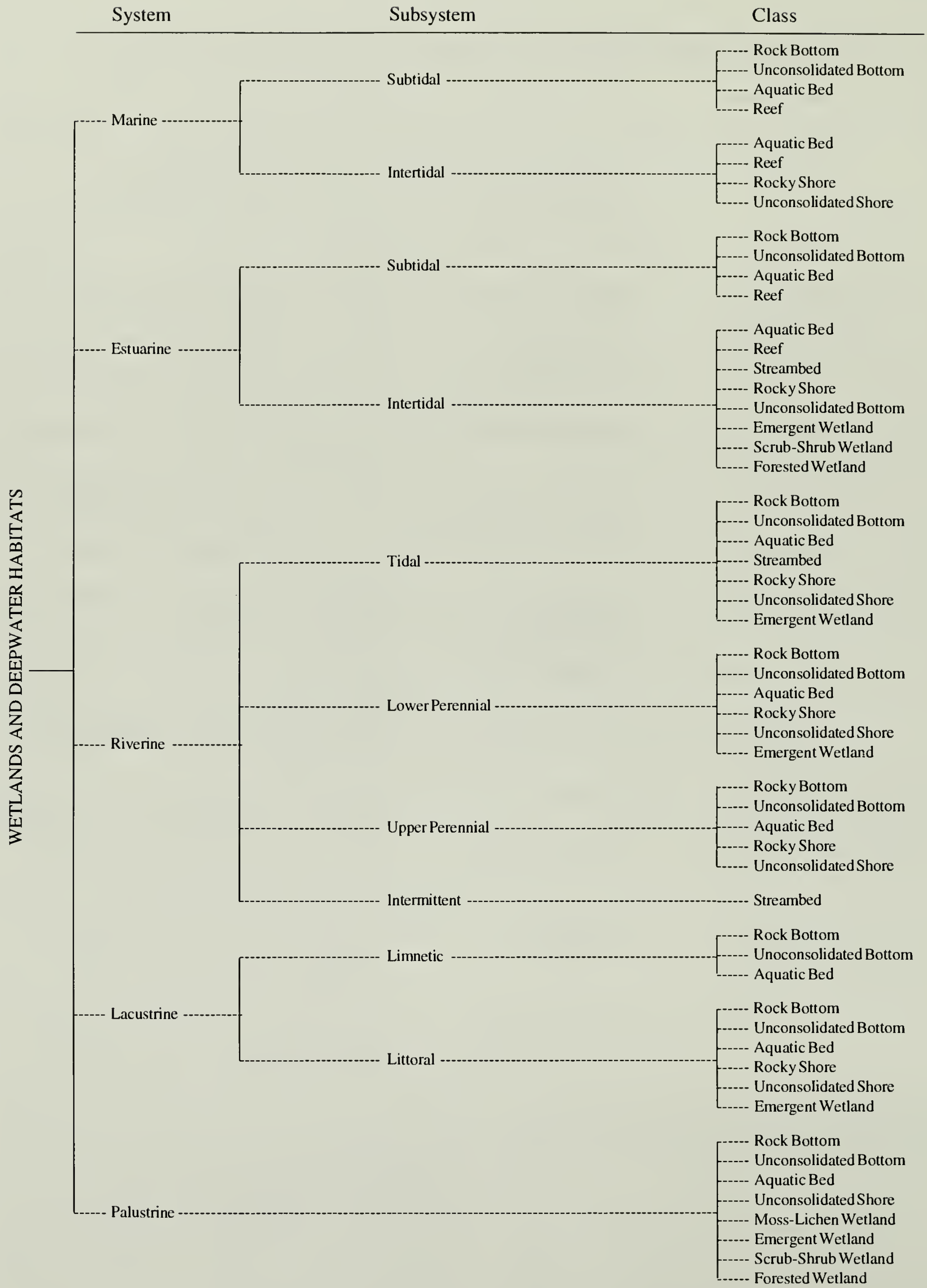

Figure 3. Classification hierarchy of wetlands and deepwater habitats showing systems, subsystems, and classes. The Palustrine System does not include deepwater habitats (Cowardin et al. 1979).

saturated or covered by shallow water during the growing season, whether or not hydrophytes or hydric soils are present. Completely drained hydric soils that are no longer capable of supporting hydrophytes due to a change in water regime are not considered wetland. Areas with completely drained hydric soils are, however, good indicators of historic wetlands, which may be suitable for restoration.

The USFWS does not generally include permanently flooded deepwater areas as wetland, although shallow waters are classified as wetland. Instead, these deeper water bodies are defined as deepwater habitats, since water, and not air, is the principal medium in which the dominant organisms live. Along the coast in tidal areas, the deepwater habitat begins at the extreme spring low tide level. In nontidal freshwater areas, this habitat starts at a depth of 2 meters (6.6 feet) because the shallow water areas are often vegetated with emergent wetland plants.

The USFWS's wetland classification system is hierarchial, proceeding from general to specific, as noted in Figure 3. In this approach, wetlands are first defined at a broad level—the system. The term "system" represents "a complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors" (Cowardin 1979:4). Five systems are defined: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. The Marine System generally consists of the open ocean and its associated high-energy coastline, while the Estuarine System encompasses salt and brackish marshes, nonvegetated tidal shores, and brackish waters of coastal rivers and embayments. Freshwater wetlands and deepwater habitats fall into one of the other three systems: Riverine (rivers and streams), Lacustrine (lakes, reservoirs, and large ponds), or Palustrine (marshes, bogs, swamps, fens, and small shallow ponds). Thus at the most general level, wetlands can be defined as either Marine, Estuarine, Riverine, Lacustrine, or Palustrine (Figure 2).

Each system, with the exception of the Palustrine, is further subdivided into subsystems. The Marine and Estuarine Systems both have the same two subsystems, which are defined by tidal water levels: (1) Subtidal—continuously submerged areas—and (2) Intertidal—areas alternately flooded by tides and exposed to air. Similarly, the Lacustrine System is separated into two subsystems based on water depth: (1) Littoral—wetlands extending from the lake shore to a depth of 2 meters (6.6 feet) below low water or to the extent of nonpersistent emergents (e.g., arrowheads, pickerelweed or spatterdock) if they grow beyond that depth—and (2) Limnetic—deepwater habitats lying beyond the 2 meters (6.6 feet) depth at low water. By contrast, the Riverine System is further defined by four subsystems that represent different reaches of a flowing freshwater or lotic system: (1) Tidal—water levels subject to tidal fluctuations—(2) Lower Perennial—permanent, flowing waters with a well-developed floodplain—(3) Upper Perennial—permanent, flowing water with very little or no floodplain development—and (4) Intermittent—channel containing nontidal flowing water for only part of the year.

The next level, class, describes the general appearance of the wetland or deepwater habitat in terms of the dominant vegetative life form or the nature and composition of the substrate where vegetative cover is less than 30% (Table 1). Of the 11 classes, five refer to areas where vegetation covers 30% or more of the surface: Aquatic Bed, Moss-Lichen Wetland, Emergent Wetland, Scrub-Shrub Wetland, and Forested Wetland. The remaining six classes represent areas generally lacking vegetation, where the composition of the substrate and degree of flooding distinguish classes: Rock Bottom, Unconsolidated Bottom, Reef (sedentary invertebrate colony), Streambed, Rocky Shore, and Unconsolidated Shore. Permanently flooded nonvegetated areas are classified as either Rock Bottom or Unconsolidated Bottom, while exposed areas are typed as Streambed, Rocky Shore, or Unconsolidated Shore. Invertebrate reefs are found in both permanently flooded and exposed areas.

Each class is further divided into subclasses to better define the type of substrate in nonvegetated areas (e.g., bedrock, rubble, cobble-gravel, mud, sand, and organic) or the type of dominant vegetation (e.g., persistent or nonpersistent emergents, moss, lichen, or broad-leaved deciduous, needle-leaved deciduous, broad-leaved evergreen, needle-leaved evergreen, and dead woody plants). Below the subclass level, dominance type can be applied to specify the predominant plants or animals in the wetland community.

To allow better description of a given wetland or deepwater habitat in regard to hydrologic, chemical, and soil characteristics, and to human impacts, the classification system contains four types of specific modifiers: (1) water regime, (2) water chemistry, (3) soil, and (4) special. These modifiers may be applied to class and lower levels of the classification hierarchy.

Table 3. Salinity modifiers for coastal and inland areas (Cowardin et al. 1979)

Coastal Modifiers[1]	Inland Modifiers[2]	Salinity (%)	Approximate Specific Conductance (Mhos at 25°C)
Hyperhaline	Hypersaline	>40	>60,000
Euhaline	Eusaline	30–40	45,000–60,000
Mixohaline (Brackish)	Mixosaline[3]	0.5–30	800–45,000
Polyhaline	Polysaline	18–30	30,000–45,000
Mesohaline	Mesosaline	5–18	8,000–30,000
Oligohaline	Oligosaline	0.5–5	800–8,000
Fresh	Fresh	>0.5	<800

[1] Coastal modifiers are employed in the Marine and Estuarine Systems.
[2] Inland modifiers are employed in the Riverine, Lacustrine and Palustrine Systems.
[3] The term "brackish" should not be used for inland wetlands or deepwater habitats.

Water regime modifiers describe flooding or soil saturation conditions and are divided into two main groups: (1) tidal and (2) nontidal. Tidal water regimes are used where water level fluctuations are largely driven by oceanic tides. Tidal regimes can be subdivided into two general categories, one for salt- and brackish water tidal areas and another for freshwater tidal areas. This distinction is needed because of the special importance of seasonal river overflow and groundwater inflows in freshwater tidal areas. By contrast, nontidal modifiers define conditions where surface water runoff, groundwater discharge, and/or wind effects (i.e., lake seiches) cause water level changes. Both tidal and nontidal water regime modifiers are presented and briefly defined in Table 2.

Water chemistry modifiers are divided into two categories which describe the water's salinity or hydrogen ion concentration (pH): (1) salinity modifiers and (2) pH modifiers. Like water regimes, salinity modifiers have been further subdivided into two groups: halinity modifiers for tidal areas and salinity modifiers for nontidal areas. Estuarine and marine waters are dominated by sodium chloride, which is gradually diluted by fresh water as one moves upstream in coastal rivers. On the other hand, the salinity of inland waters is dominated by four major cations (i.e., calcium, magnesium, sodium, and potassium) and three major anions (i.e., carbonate, sulfate, and chloride). Interactions among precipitation, surface runoff, groundwater flow, evaporation, and sometimes plant evapotranspiration form inland salts which are most common in arid and semiarid regions of the country. Table 3 shows ranges of halinity and salinity modifiers which are a modification of the Venice System (Remane and Schlieper 1971). The other set of water chemistry modifiers are pH modifiers for identifying acid (pH < 5.5), circumneutral (pH 5.5–7.4) and alkaline (pH > 7.4) waters. Some studies have shown a correlation between plant distribution and pH levels (Sjors 1950; Jeglum 1971). Moreover, pH can be used to distinguish between relatively mineral-rich (e.g., fens) and mineral-poor wetlands (e.g., bogs).

The third group of modifiers, soil modifiers, is presented because the nature of the soil exerts strong influences on plant growth and reproduction as well as on the animals living in it. Two soil modifiers are given: (1) mineral and (2) organic. In general, if a soil has 20% or more organic matter by weight in the upper 40 centimeters (16 inches), it is considered an organic soil; whereas if it has less than this amount, it is a mineral soil. For specific definitions, please refer to Appendix D of the USFWS's classification system (Cowardin et al. 1979) or to *Soil Taxonomy* (Soil Survey Staff 1975, 1992). See Chapter 5 for discussion of hydric soils in the study area.

The final set of modifiers, special modifiers, was established to describe the activities of people or beaver affecting wetlands and deepwater habitats. These modifiers include excavated, impounded (i.e., to obstruct outflow of water), diked (i.e., to obstruct inflow of water), partly drained, farmed, and artificial (i.e., materials deposited to create or modify a wetland or deepwater habitat).

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CHAPTER 3. NATIONAL WETLANDS INVENTORY MAPPING TECHNIQUES AND RESULTS

INTRODUCTION

The National Wetlands Inventory Project uses remote sensing techniques with supplemental field investigations for wetland identification and mapping. High-altitude aerial photography, ranging in scale from 1:58,000 to 1:80,000, serves as the primary remote imagery source. Once suitable high-altitude photography is obtained, there are seven major steps in preparing wetland maps: (1) field investigations, (2) photo interpretation, (3) review of existing wetland information, (4) quality assurance, (5) draft map production, (6) interagency review of draft maps, and (7) final map production. Steps 1, 2, and 3 encompass the basic data collection phase of the inventory. After publication of final wetland maps for ANP and vicinity, the USFWS (through funding by the NPS) constructed a digital wetland database for the ANP. All NWI maps were digitized and data entered into a computer. This system generated acreage data for wetlands and deepwater habitats at three scales: (1) the entire study area, (2) ANP, and (3) individual towns within the study area. The procedures used to inventory ANP's wetlands and the results of this inventory are discussed in the following sections.

WETLANDS INVENTORY TECHNIQUES

Mapping Photography

For mapping ANP's wetlands, the USFWS used 1:58,000 color-infrared photography acquired during the spring of 1983 (May 1983). With this scale, the minimum mapping unit (mmu) for wetlands was roughly one acre in size, yet some larger wetlands may be missed due to the difficulty of detecting them through remote sensing techniques (see following subsection). Some wetlands smaller than the mmu were mapped where conspicuous (e.g., ponds).

Photo Interpretation and Collateral Data

Photo interpretation was performed by Geonex of St. Petersburg, Florida, and reviewed by Glenn Smith of the USFWS's NWI Project, Hadley, Massachusetts. It was done in stereo using mirror stereoscopes. Photo interpretation was done in accordance with standard NWI conventions. Farmed wetlands were not mapped due to national policy, largely based on the technical difficulties of identifying these areas with just one date of photography. These areas are not significant in the Acadia region. (Note: the SCS is currently mapping farmed wetlands using multi-year photos.) Collateral data sources used to aid in wetland detection and classification included

1. U.S. Geological Survey topographic maps;
2. SCS soil surveys;
3. Existing USFWS existing NWI maps;
4. NPS landuse and land cover maps for ANP.

Wetland photo interpretation, although extremely efficient and accurate for inventorying most wetlands, does have certain limitations (Tiner 1990). Consequently, some problems arose during the course of the survey. Additional field work or use of collateral data was necessary to help overcome these constraints. These problems and their resolution are discussed below.

1. Identification of freshwater aquatic beds and nonpersistent emergent wetlands. Due to the use of spring photography, these wetland types were not interpretable. Review of existing land use and land cover maps for ANP allowed identification of these areas.

2. Inclusion of small upland areas within delineated wetlands. Small islands of higher elevation and better-drained uplands naturally exist within many wetlands. Due to the minimum size of mapping units, small upland areas may be included within designated wetlands. Field inspections and/or use of larger-scale photography were used to refine wetland boundaries when necessary.

3. Brackish water/freshwater and tidal/nontidal boundary breaks and associated wetland classification. Boundaries designated by the original NWI maps were used. The general limits of these areas were often checked during routine field investigations. Boundaries should be considered approximate.

4. Delineation of intertidal flats. These areas were delineated as they appeared on the aerial photos since photography was captured at low tide.

5. Delineation of evergreen forested wetlands and some mixed evergreen/deciduous forested wetlands. These wetlands are among the most difficult to identify through photo interpretation (Tiner 1990) or other remote sensing techniques. Additional field work and consultation of existing landuse and land cover maps for ANP allowed identification of numerous evergreen forested wetlands. However, there remains an unknown number of similar wetlands that were not detected during this survey. Field checking of depressional and broad, flat areas may reveal unmapped wetlands.

Field Investigations

Ground-truthing surveys were conducted to collect information on plant communities of various wetlands and to gain confidence in detecting and classifying wetlands from aerial photography. Detailed notes were taken at more than 90 sites throughout the study area. In addition to these sites, observations were made at countless other wetlands for classification purposes, and notations were recorded on appropriate topographic maps. In total, approximately 20 weeks were spent evaluating ANP's wetlands, including field work by USFWS and University personnel.

Draft Map Production

Upon completion of photo interpretation, two levels of quality assurance were performed: (1) regional quality control and (2) national consistency quality assurance. Regional review of each interpreted photo was accomplished by USFWS Northeast Regional Office's NWI staff to ensure identification of wetlands and proper classification. By contrast, national quality control by the NWI Group at St. Petersburg, Florida, entailed spot checking of photos to ensure that national standards had been successfully followed. Once approved by quality assurance, draft large-scale (1:24,000) wetland maps were produced by the NWI's support service contractor using zoom transfer scopes.

Draft Map Review

Draft maps were reviewed by personnel at the USFWS, ANP, and the University of Maine. In addition, the USFWS's NWI staff conducted a thorough examination of draft maps to ensure proper placement of wetland polygons and labels as well as accurate classification.

Final Map Production

All comments received were evaluated and incorporated into the final maps, as appropriate. Final maps were published in 1992.

Wetland Map Database Construction

Upon publication of the final NWI maps for the Acadia region, the USFWS began construction of a wetland map database for the study area by digitizing NWI maps. The database was completed in mid-1992. This database can generate town and watershed wetland area summaries when combined with ANP's geographic information system.

RESULTS

National Wetlands Inventory Maps

A total of 14 1:24,000 wetland maps were produced for the study area. The size, shape, and classification of wetlands within the study area are in accordance with NWI specifications.[1] Figure 4 depicts a portion of a large-scale map used in the inventory.

Wetland Area Summaries

Study area totals

The Acadia region has 12,846 hectares (31,730 acres) of wetland area. This number does not include wetlands in the Marine and Riverine Systems that appear as linear features on wetland maps or wetlands smaller than the minimum mapping unit (0.3 hectare). Eighteen percent of all land located within the study area is classified as wetland. Fee ownership lands within ANP include 11% wetland at the time of boundary legislation in 1986. In addition, 5% of lands held under conservation easements by the NPS is categorized as wetland.

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[1]Final maps have been available since 1980. Copies of NWI maps and a map catalogue can be ordered from Maine Geological Survey, State House Station 22, Augusta, ME 04333, (207) 289-2801.

Figure 4. National Wetlands Inventory map depicting wetlands in the vicinity of Big Heath, Acadia National Park, Mount Desert Island, Maine.

The majority of wetlands within the study area fall within two systems: Marine (38%) and Palustrine (32%) (Table 4). Aquatic beds (69%) and areas lacking vegetation (e.g., unconsolidated bottom, rocky shore) (31%) constitute the Marine System. Palustrine wetlands are dominated by forested or scrub-shrub wetland communities (86%).

Of the 9000 wetland units mapped in the region, more than 40% were palustrine (Figure 5), mostly scrub-shrub (1340), and forested (1111). The majority of palustrine wetlands are <0.5 hectares in size (Figure 6). Moreover, greater than three-quarters of these wetlands are not regulated by the state as they are less than 2.4 hectares (10 acres) in size. Eighty-eight percent of all hydric soils in the region support palustrine wetlands (Table 5). The distribution of hydric soils is shown in Figure 7.

Wetland ownership

Wetland acreages are presented by township in Table 6. The study area includes wetlands within 19 town.[2] Nearly 50% of the wetland area is in three towns: Bar Harbor (18%), Gouldsboro (16%), and Mount Desert (14%). Bar Harbor contains 25% of all palustrine wetlands classified within town boundaries.

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[2]Discrepancies between wetland numbers by study area and townships are due to town boundaries which do not always encompass coastal and marine lands (especially beyond mean high water).

Table 4. Wetland area summaries and percentages of wetland area for Acadia National Park and vicinity.

System	Class	Hectares[1]	% Area	% of Total Wetland Area for Each System
Marine	Aquatic Bed	3,307	69	
	Reef	6	<1	
	Rocky Bottom/Shore	774	16	
	Unconsolidated Bottom/Shore	731	15	
Total		4,818		37.5
Estuarine	Aquatic Bed	399	15	
	Emergent	240	9	
	Rocky Shore	14	1	
	Unconsolidated Shore/Bottom	1,922	65	
Total		2,575		20
Riverine	Unconsolidated Bottom	3	100	
Total		3		.02
Lacustrine	Aquatic Bed	1,353	98	
	Unconsolidated Bottom	28	2	
Total		1,381	10.7	
Palustrine	Aquatic Bed	16	<1	
	Emergent	381	9	
	Forested	1,940	48	
	Scrub-shrub	1,530	38	
	Unconsolidated Bottom/Shore	202	5	
Total		4,069		31.6
TOTAL		12,847		

[1] For conversion from hectares to acres, multiply by 2.47
Source: Acadia National Park

Table 5. Area (ha) of hydric soils within wetland systems in Acadia National Park and vicinity.

	Hectares[1]	%
Marine	39	2.7
Estuarine	119	8.0
Riverine	2	0.1
Lacustrine	10	0.7
Palustrine	1,297	88.5
TOTAL	1,465	100.0

[1] For conversion from hectares to acres, multiply by 2.47
Source: Acadia National Park

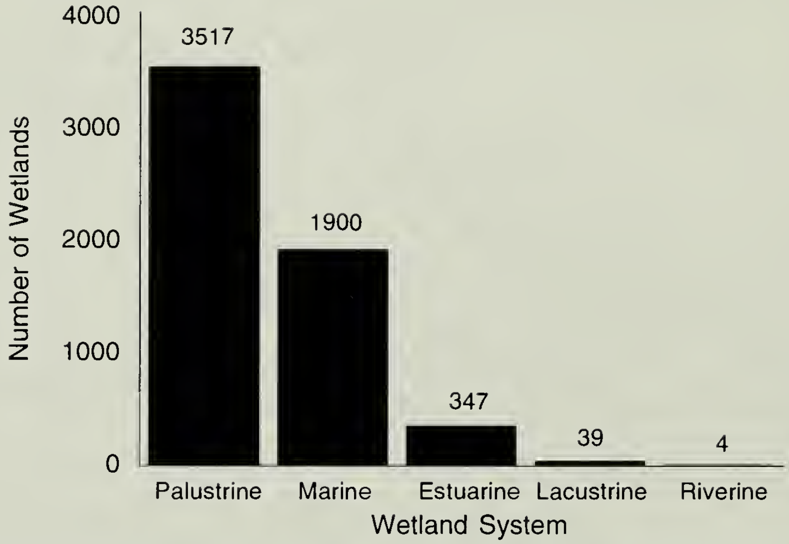

Figure 5. Number of wetland units by system in Acadia National Park and vicinity. A wetland unit is classifiable wetland (e.g., palustrine forested) greater than 0.3 hectare (Source: Acadia National Park).

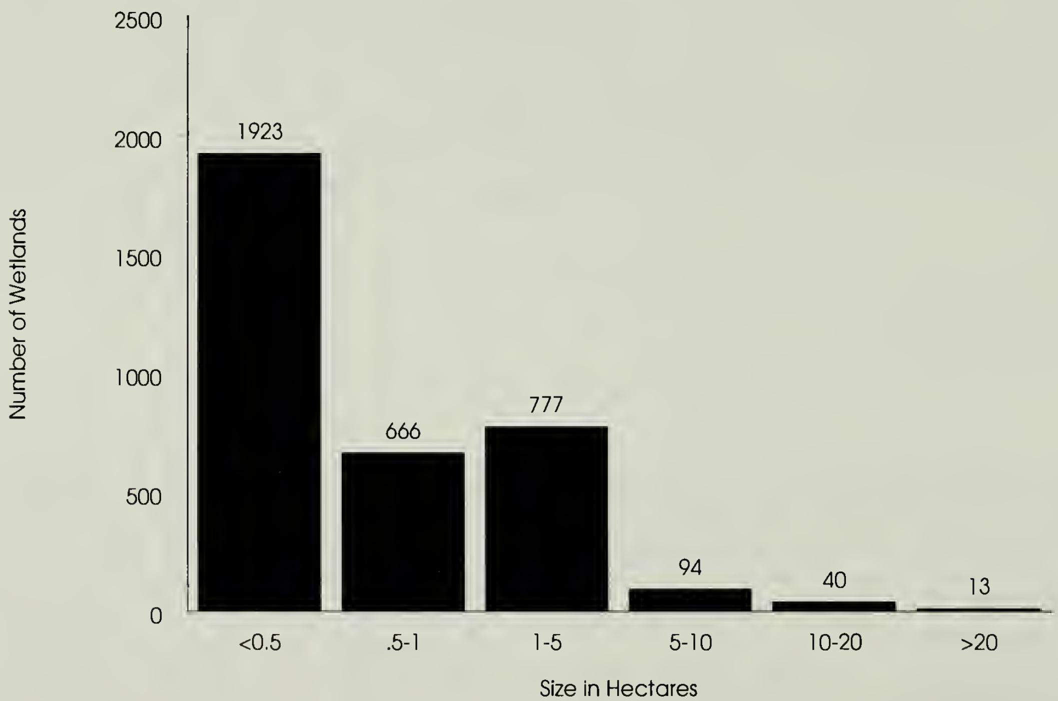

Figure 6. Distribution of palustrine wetlands by size class in Acadia National Park and vicinity (Source: Acadia National Park).

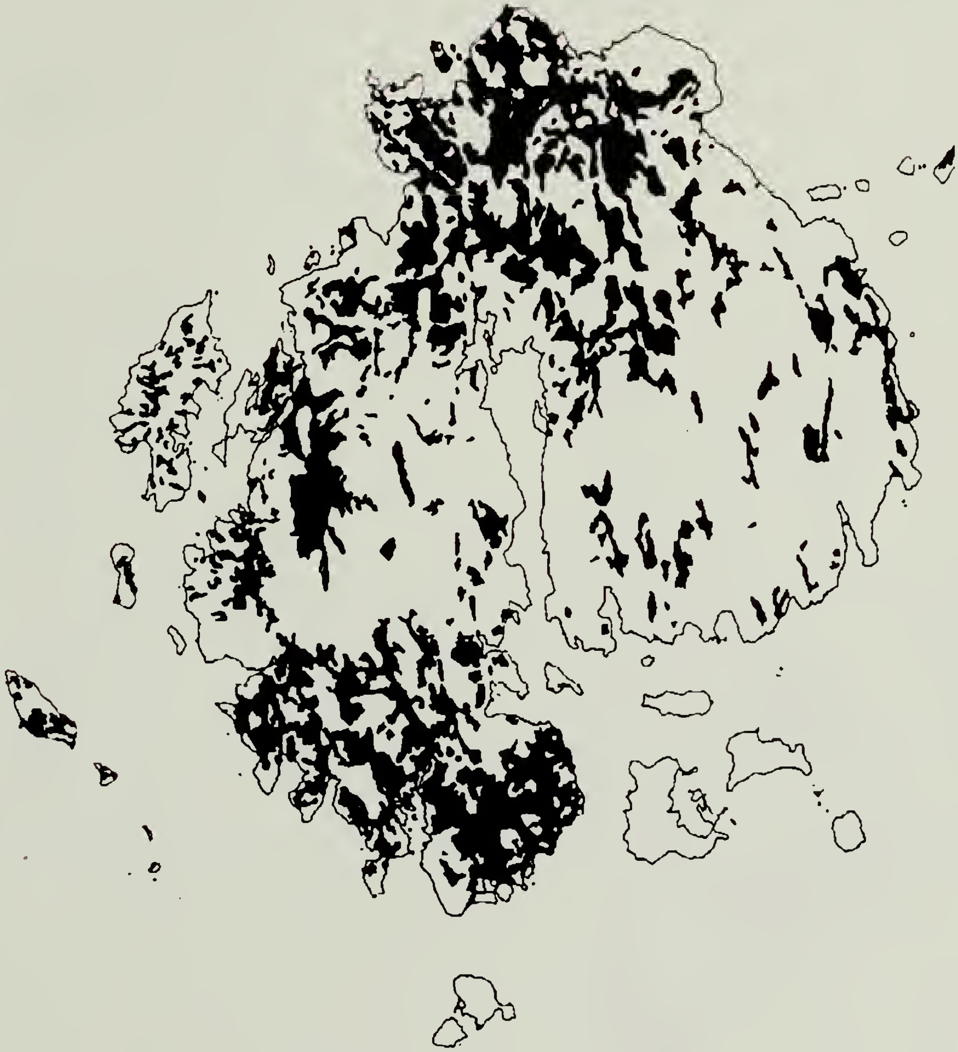

Figure 7. Distribution of hydric soils on Mount Desert Island (a portion of the study area) (Source: Acadia National Park).

Palustrine wetlands were represented in all towns, and marine wetlands were in all towns with the exception of T7SD. Riverine wetlands are less abundant and were mapped only in Bar Harbor and Tremont. Figure 8 shows the area represented by each of the five wetland systems in the Acadia region.

SUMMARY

The NWI project completed an inventory of ANP and vicinity along the mid-coast of Maine using aerial photography and intensive field methods. Wetlands represent nearly 20% (12,847 hectares) of the total land area of the Acadia region and greater than 10% of ANP. Wetlands in the Marine and Palustrine Systems are dominant.

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Table 6. Wetland area and frequency summaries by township for Acadia National Park and vicinity.

	Wetland System										
	Marine		Estuarine		Riverine		Lacustrine		Palustrine		Total
	ha	freq.	ha	freq.	ha	freq.	ha	freq.	ha	freq.	Area (ha)
Bar Harbor	405	134	67	34	2	3	248	10	1,008	990	1,730
Blue Hill	24	29							3	4	27
Cranberry Isles	287	77	4	5					119	57	410
Frenchboro	237	88							40	62	277
Gouldsboro	333	117	177	64			311	4	718	543	1,539
Hancock	68	29	17	9					11	30	96
Isle au Haut	376	175					25	1	143	114	544
Lamoine	42	22	66	61			14	1	46	81	168
Mount Desert	263	123	162	78			577	22	331	433	1,333
Sorrento	75	40							19	34	94
Southwest Harbor	90	35	37	16			95	4	285	228	507
Sullivan	5	5							19	34	24
Surry	147	72	3	6					92	76	242
Swans Island	336	242	9	8					234	228	579
T7SD									39	26	39
Tremont	263	121	83	46	1	1	107	5	205	215	659
Trenton	62	40	32	23					373	182	467
Winter Harbor	230	78	52	24					253	174	535
TOTAL AREA	3,243		709		3		1,377		3,938		9,270

Source: Acadia National Park

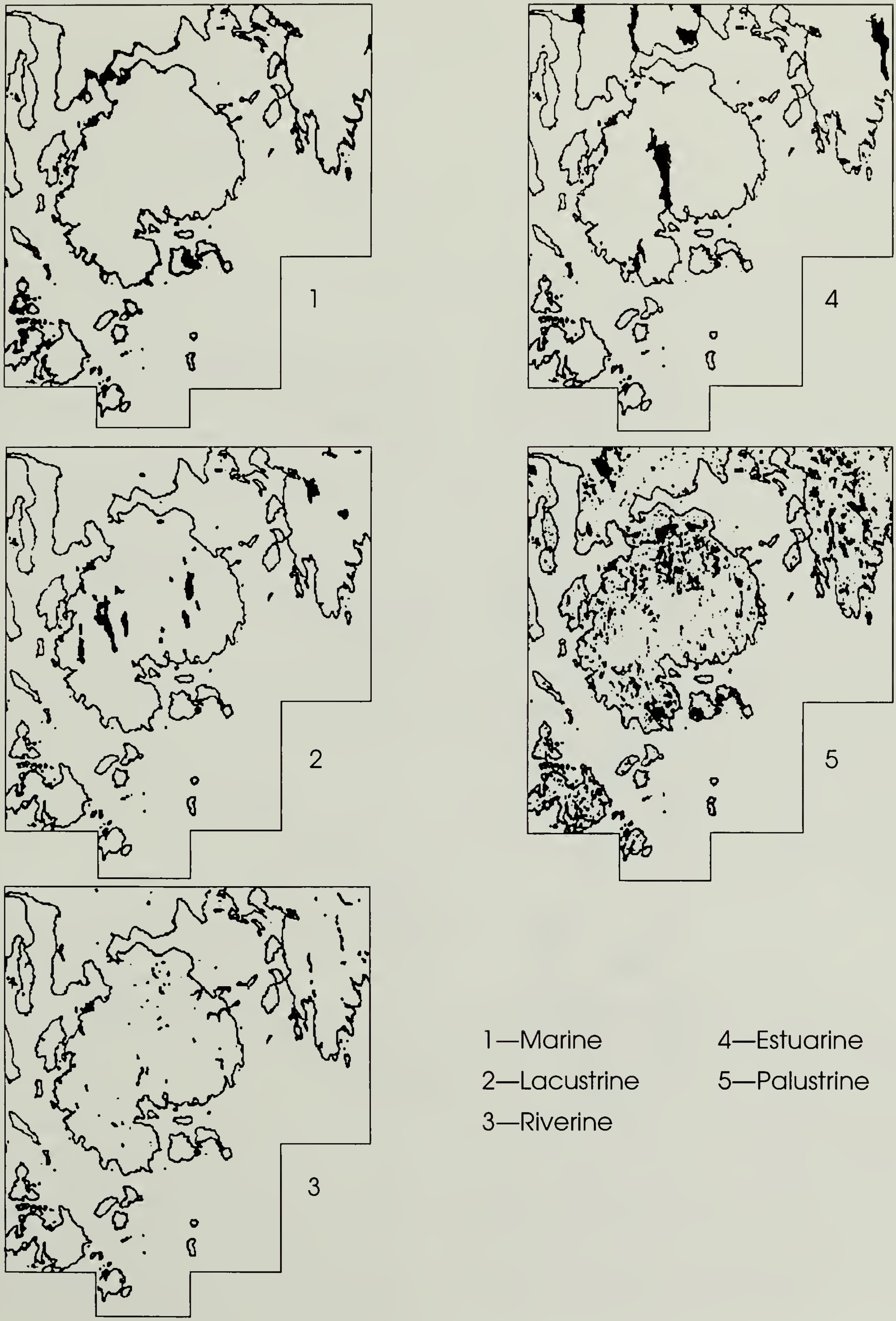

Figure 8. Distribution of the five wetland systems in Acadia National Park and vicinity (Source: Acadia National Park).

CHAPTER 4. WETLAND FORMATION AND HYDROLOGY IN THE ACADIA REGION

INTRODUCTION

The Acadia region has a wealth of wetland settings owing to coastal influences and geologic and glacial history. The mountainous eastern region of MDI supports wetlands along drainageways and groundwater discharge areas in the low-lying coastal valleys, in depressions in till and bedrock landscapes which intercept the water table or have impaired drainage, along the shores of lakes and ponds, and nestled in coves and tidal streams associated with the rugged rocky coastline. Wetlands in the Marine System, including cobble/gravel shores, sand beaches, and rockweed bedrock shores, are characteristic of eastern MDI and easily observed along the Park Loop Road. Western MDI, with a gentler landscape and more protected shores, supports the majority of the island's estuarine wetlands (salt marshes and intertidal mudflats), peatlands, and riverine wetlands. The Cranberry Isles, Swans Island, Isle au Haut, and others, with moist, cool, foggy climates, support ombrotrophic peatlands and hillside seep forested wetlands as well as estuarine and marine wetlands, depending on exposure to open ocean.

This chapter briefly establishes the geomorphic processes that set the stage for the formation of wetlands in the Acadian landscape. The hydrologic factors and processes that drive the establishment of and differentiation among wetlands are also addressed. This hydrogeologic setting provides the foundation for the evolution of hydric soils and plant communities described in this report.

GEOLOGIC HISTORY

The modern landscape has been forming for hundreds of millions of years (Gilman et al. 1988). Geologic processes dating back 550 million years have created the substrate for the region, erosive forces have carved it and reshaped it with sediments, and climatic and ecological patterns have garnished it with wetlands. Some of these processes are ongoing and easily observed, such as streams carrying loads of suspended sediments and winter frost heaving soil particles upward to be dropped into spring meltwater channels. Other forces affecting wetland distribution, including glacial erosion and redistribution of materials, are not readily observable, but are recorded in the rocks and the configuration of the landscape.

Continental glacial activity has been the most significant geologic process shaping the present-day New England landscape. Approximately 1.7 million years ago, an unprecedented climatic epoch dramatically influenced much of the earth's surface. Successive periods of global cooling, coupled with plentiful snowfall in many regions, allowed the accumulation of vast snow fields and the formation of continental glaciers. Ice accumulation centered in Labrador and the western Hudson Bay region, extending nearly 300 kilometers (180 miles) beyond the present coastline to Georges Bank, blanketed the state of Maine with ice over a kilometer thick.

The moving glacier greatly intensified the erosion of the Acadian landscape. Vast flowing ice incorporated loose soil and rock materials into its mass, scraping bedrock and grinding rocks into fine flour. Land materials were picked up and scoured from the surface, squeezed into depressions and onto obstructing slopes, and abandoned in place when the ice finally melted.

The Balanced Rock remains poised on MDI's South Bubble, a remnant of the transporting abilities of flowing ice. Depressions and valleys carved by the glacier, often in areas of less resistant rock or preexisting drainageways, later became water catchments. Jordan Pond, adjacent to the Jordan Pond House, typifies a glacially carved basin trapping mountain water (Figure 9).

Global temperatures began to warm about 18,000 years ago, and the ice lobes of the last glacier receded, exposing lowland areas between 12,000 and 10,000 years ago (Gilman et al. 1988). Meltwaters left sorted deposits of sand and gravel within the ice and close to its margins. Finer silts and clays remained in suspension, eventually settling out in quiet, deep ocean and debris-dammed lake waters.

As the ice melted back towards the north, ocean waters encroached on the depressed land surface and extended up Maine's major river courses. Sediments of the Presumpscot formation mark the route. The upper marine limit on MDI reached at least 80 meters (265 feet) above current sea level, as evidenced by well-developed boulder beaches on Day Mountain and Cadillac cliffs (Smith 1966). Figure10a shows an interpretation of MDI's coastline during glacial retreat.

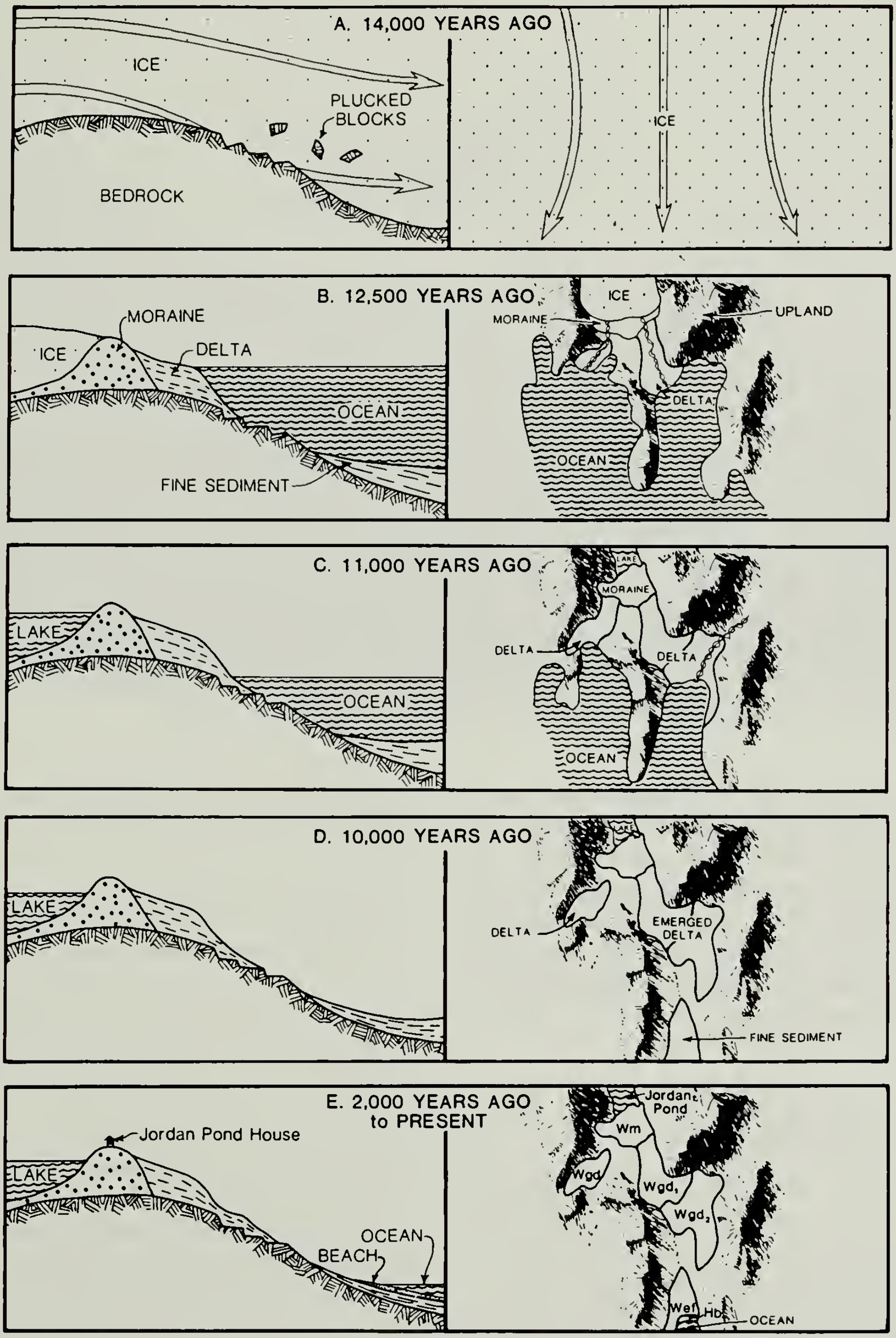

Figure 9. Glacial landscape forming Jordan Pond (Gilman et al. 1988).

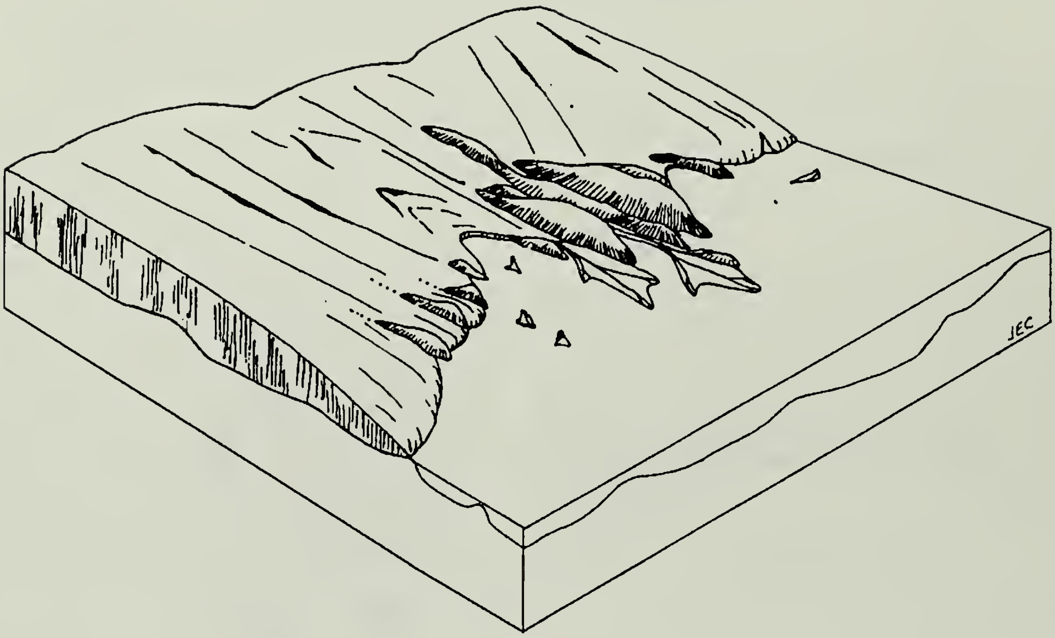

Figure 10a. Mount Desert Island during deglaciation. Ice tongues linger in the valley, while the ridges are ice free. (Redrawn by J.E. Cormier from Lowell and Borns 1988; Tucker 1985.)

The land began a slow process of isostatic rebound from the colossal weight of the glacial ice (Stuiver and Borns 1975). Eventually ocean waters were drained from the land, establishing a shoreline similar to the present one. Newly exposed marine sediment beds appeared in low-lying areas, and these deposits commonly support relatively extensive wetland complexes.

FRESHWATER WETLAND FORMATION

A raw, erosive land was uncovered by the receding glacier and retreating ocean water before tundra plant communities became established. Glacial drift blocked some stream channels, trapping water. Streams, enlarged by a cool, moist climate, deeply cut their valleys. Soil material thus eroded often settled out further downstream, creating other temporary or permanent water impoundments. Lakes, clouded with silts and clays, accumulated impermeable sediments in their beds.

The climate warmed slowly and plant communities succeeded in stabilizing the terrain. Forests formed over this region between 11,000 and 10,000 years ago (Davis and Jacobson 1982). As the land was revegetating, wetland communities began to develop in positions of restricted drainage within the glacial landscape.

Wetland Formation in Glacial Lakes

Shallow lakes supported aquatic plants, which in turn produced organic sediments. As sediments accumulated, emergent marsh communities often replaced the aquatic beds. Following this development, forested wetlands now occupy many depressional areas where organic materials are over a meter thick, but ground or surface waters supply sufficient nutrients for tree growth.

Other lake beds eventually yielded to raised ombrotrophic bogs (Gk. *Ombros* = rain; Gk. *trophe* = food) through successional processes which led to a build-up of organic material. Sufficient organic matter had accumulated in these ecosystems to transform the peatland surface into a gently "raised" convex shape, separating the surface from the mineral rich substrate and groundwater below. The bog is able to continue growing, producing peat faster than it can decompose, fed only by atmospheric deposition through rainwater and dry fallout (Davis and Anderson 1991). Coastal Maine supports a variety of raised bogs, including Big Heath on MDI and The Heath on Great Cranberry Isle.

Figure 10b. U-shaped valley at the south end of the Tarn.

Depressional areas still supporting lakes may develop wetland plant communities in shallow sections (submergent and floating aquatic beds) and around lake margins where semi-permanently flooded, nonpersistent marshes and seasonally flooded/seasonally saturated persistent marshes or scrub-shrub wetlands often form.

Wetland Formation in Glacial Valleys and Streambeds

MDI is transected by glacially carved valleys generally trending northwest to southeast (see Figure 10b). Valleys with significant watersheds still support streams that flow through riverbeds formed by the larger rivers that drained and shaped the postglacial landscape (Kelley et al. 1988). Wetlands develop in these drainageways, bounded by streams on one side and valley walls on the other. The Bass Harbor Marsh complex is an example of this phenomenon, as both salt marsh and freshwater wetlands have developed along the streams draining into Bass Harbor. Often along slow, meandering streams, such as Adams Brook and the upper sections of Aunt Betsy's Brook, the water table remains high beyond the brook margins. Hydrophytic plant communities dominate these positions, producing organic soils or peats.

Similarly, water tables in relic stream valleys remain high, supplemented by overland and subsurface flow from surrounding watersheds. Wetlands may form in these areas as well. The valley bounded by Champlain Mt. to the west and Cranberry Hill to the east is an example of this.

Wetlands also form along smaller brooks and streams (often in narrow strips adjacent to the waterway) or in braided stream channels with seasonally high water tables or subjected to stream flooding. Shrub swamps and forested wetlands are common in this situation.

Wetland Formation in Till Landscapes

Moist climate, cool air temperatures, and dense soil substrata have supported wetland formation in areas that were never lakes and are not associated with stream waters. Glacial tills (unsorted glacial debris compacted by the weight of the glacier) with glacially lodged, compacted substrata are intermittently exposed throughout the Acadian landscape. Though frost action and living organisms have loosened the soil surface layers, dense substrata perch water for long periods. In low topographic positions, water may be perched for part of the growing season. The resulting poorly and very poorly drained soils support a number of wetland classes including emergent, shrub, and forested wetlands. Examples of wetlands forming in a till landscape are abundant in the western portion of MDI between Pretty Marsh Harbor and the northern end of Long Pond.

In the lowest positions in till landscapes, the water table is intercepted. In these situations, organic materials may accumulate to a greater depth than in tills where the water table is perched. Wetlands associated with this setting include fens and bogs.

Hillside seeps, or wetlands occurring on slopes, are associated with till landscapes. Water perched above a restrictive layer seeps out along the surface of the hillside forming a network of springs which saturate the soil long enough during the growing season to support hydrophytic vegetation. This situation is more common on the smaller islands where foggy, moist, cool coastal climates conspire to support hillside wetland communities. Forested wetlands (described in Chapter 6) commonly occupy these sites in the Acadia region.

Wetland Formation in Glaciomarine Sediments

Extensive glaciomarine sediment beds support wetland complexes including emergent, shrub, and forested wetlands. Water-sorted silts, clays, and sands occupy low-lying landscape positions and remain saturated from September through June, with the wettest sites potentially saturated through August. Wetlands form in these areas largely owing to a position in the landscape that intercepts the water table.

Thick deposits of heavy silts and clays of the Presumpscot formation, typical on the mainland coast, are not common in low-lying positions in the Acadia region. Large marine sediment beds (e.g., Big Heath wetland complex and the area around Jones Marsh) contain only thin (less than 1 meter) strata of the heavy Presumpscot formation materials. By contrast, the backs of small coves and narrow drainageways that were inundated by postglacial ocean waters (e.g., Compass Harbor and Hunter's Brook) contain, under sandy sediments, Presumpscot clays 3–4 meters thick in slightly higher positions (T. Lowell, University of Ohio, pers. comm.). One theory suggests that the sediment supplied by the upland was deposited at the mouths of streams as water velocity slowed at the ocean/stream interface. This allowed a buildup of deposits. In large, flat areas of postglacial ocean floor under shallow waters of intermediate energy, however, substantial fine sediment from inland sources was unavailable, resulting in shallow deposits. The Acadia region was subjected to complex and dynamic environmental factors in postglacial times, and no simple model can explain the complex sediment patterns observed in the region's wetlands.

TIDAL WETLAND FORMATION

The glaciated landscape interacts with rising sea level and oceanic tides to form coastal, or tidal, wetlands. Geologic, erosive, and glacial processes have left eastern Maine with a distinctly convoluted coastline protected by larger islands such as MDI, and peppered with many smaller exposed islands such as the Cranberry Isles and Isle au Haut. MDI is divided nearly in two by Somes Sound, a fjord cut deeper than sea level by glacial ice (Kendall 1987).

Coastal wetland formation in the Acadia region is best described by Kelley et al. (1988) in their description of the origin and morphology of salt marshes along the glaciated coast of Maine. They divide the coast into four compartments based on variation in rock composition and structure. The study area falls within the largest compartment, the Island-Bay complex, which extends from Penobscot Bay to Machias Bay (Figure 11).

Marine Wetlands (High-Energy Coastline)

The Island-Bay complex, with its broad embayments, is more exposed than southern coastal areas. The numerous islands provide some protection from waves; however, this region is still dominated by high-energy coastal wetland features including cobble/gravel beaches, coarse-grained flats, and exposed rock, with salt marsh development less extensive than in southern compartments. Ocean tides and storm surges produce protective sand and cobble seawalls. The Seawall, near the southern tip of MDI, protects the pond behind it from the stormy waters that shape its cobbly flanks. Sand Beach protects the tidal stream associated with it as well as adjacent wetlands from the full force of the surf (Plate 2).

Vegetated marine wetlands are common in eastern MDI and along the coast of the smaller, exposed islands where the salt water crashes against the steep, rocky terrain. Here, rockweed/bedrock associations dominate the intertidal region, with marine aquatic beds developing in subtidal zones.

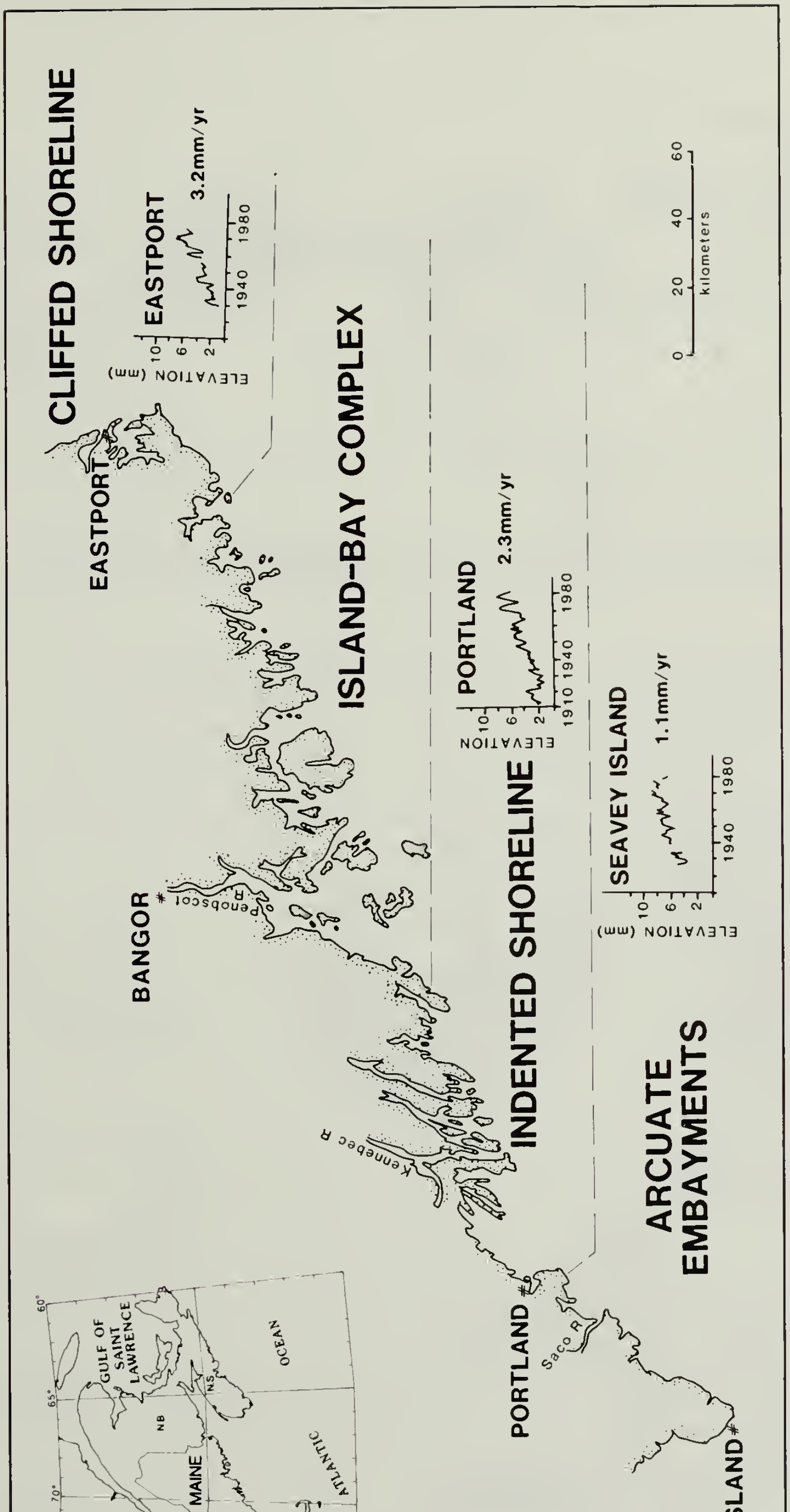

Figure 11. Coastal compartments of the Maine coast based on variation in rock composition and structure (Kelley et al. 1988).

MAINE SALT MARSH GEOMORPHOLOGY

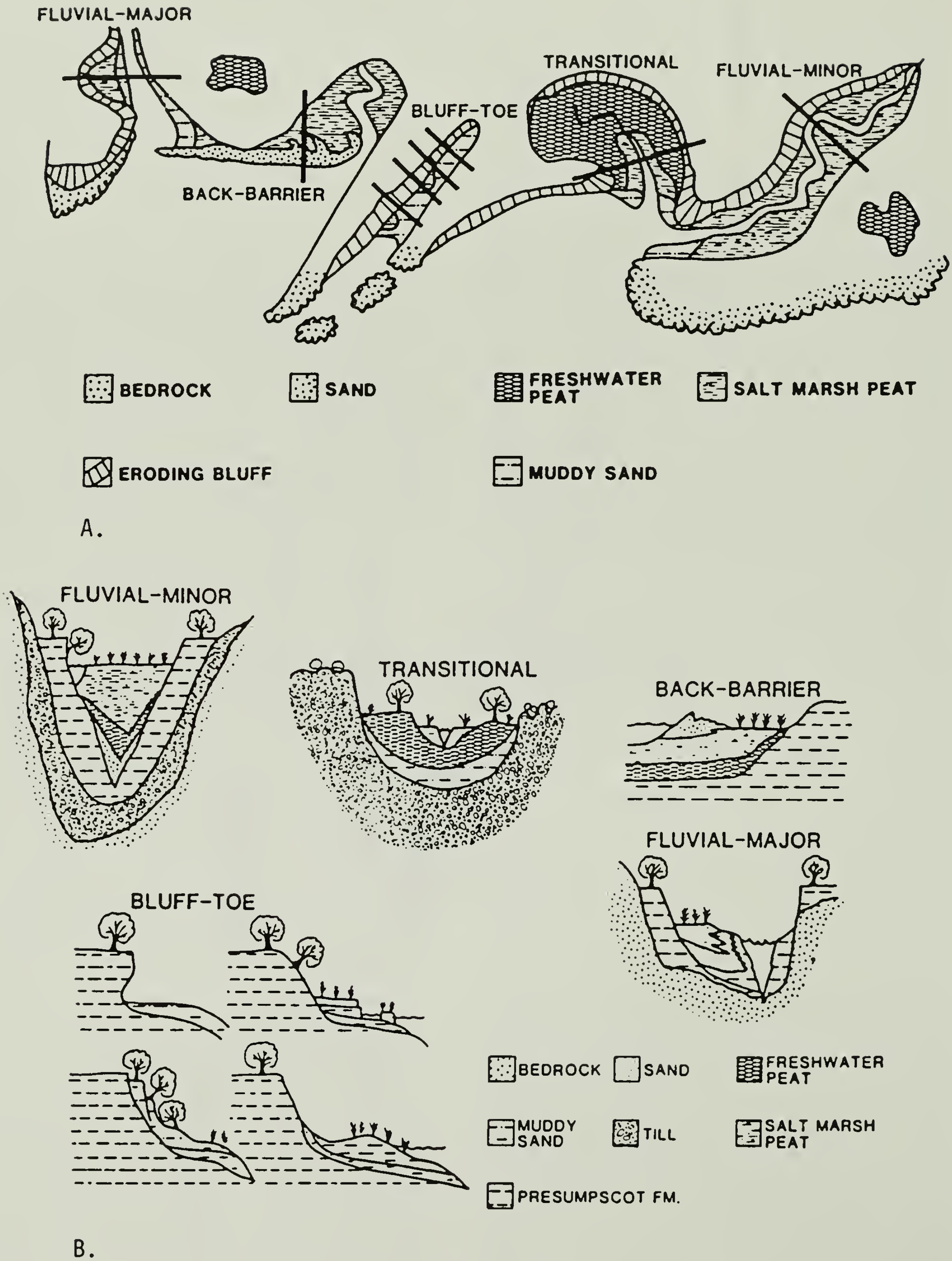

Figure 12. Maine salt marsh geomorphology (Kelley et al. 1988).

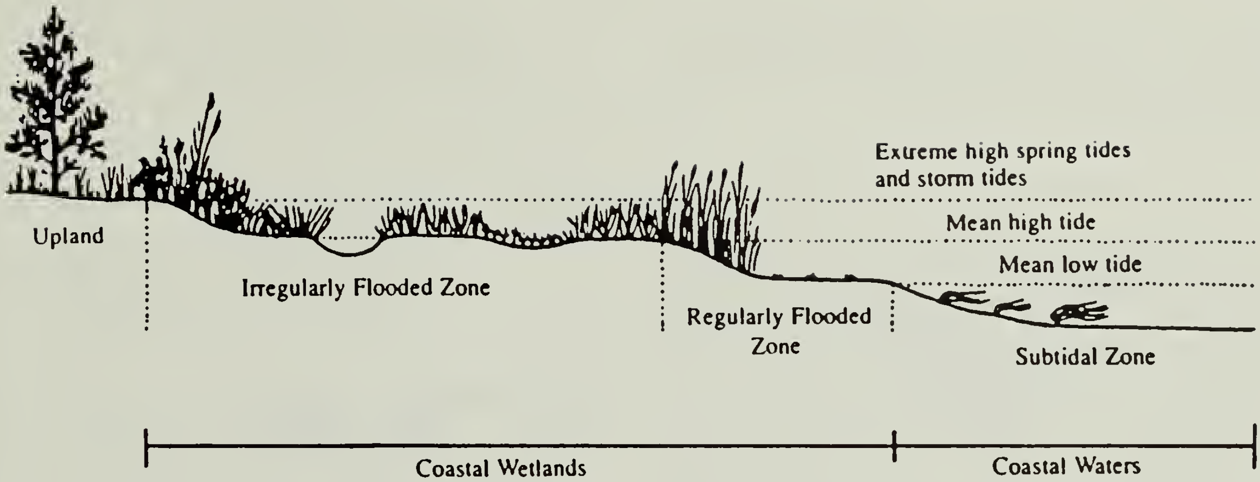

Figure 13. Hydrology of coastal wetlands showing different zones of flooding. The regularly flooded zone is flooded at least once daily by the tides, while the irregularly flooded zone is flooded less often (Tiner 1987).

Table 7. Tidal ranges on Mount Desert Island and vicinity.

Location	-------- Range (m) -------- Mean	Spring
Mount Desert Narrows	3.20	3.69
Bar Harbor	3.23	3.72
Southwest Harbor	3.11	3.57
Bass Harbor	3.02	3.44
Pretty Marsh Harbor	3.11	3.57
Isle au Haut	2.83	3.26

Source: National Oceanic and Atmospheric Administration. 1992.

Table 8. Examples of plant indicators of tidal water regimes for the Acadia region's estuarine wetlands.

Water Regime	Indicator Plants
Regularly Flooded	*Spartina alterniflora* (smooth cordgrass—tall form) *Fucus* spp. & *Ascophyllum* spp. (rockweeds)
Irregularly Flooded	*Spartina patens* (salt marsh hay) *Juncus gerardii* (black grass) *S. alterniflora* (smooth cordgrass—short form) *Agrostis alba* var. *palustris* (creeping bent grass) *Carex paleacea* (chaffy sedge)

Estuarine Wetlands (Low-Energy Coastline)

Salt marsh communities are best developed on western MDI and within the sheltered coves of the smaller islands. In the Island-Bay complex, Kelley et al. (1988) found extreme coastal relief prevented extensive marshes from forming except in preglacial river valleys, which are the major loci of marshes in this compartment. Furthermore, the relatively rapid rate of sea level rise (2–3 mm/yr) and the large tidal range (3.1 meters) would require large amounts of sediment input (for vertical and lateral accretion of marshes) if extensive salt marsh systems were to develop. On MDI, the major salt marshes (Bass Harbor Marsh, Pretty Marsh) have developed in relatively large bedrock valleys today occupied by very small streams. Such streams are termed "underfit" because they are too small for their bedrock valleys as a consequence of glaciation (Kelley et al. 1988; Tolonen et al. 1988). Marshes developing in this hydrogeologic setting are termed fluvial minor marshes by Kelley et al. (1988). Bass Harbor Marsh exemplifies the fluvial minor marsh setting. Quiet tidal waters encroach into old river valleys, carrying salt water and suspended sediments inland to mingle with fresh water and stream sediments. For the time being, the marsh is keeping pace with rising sea level as the accumulation of organic materials and suspended particles continue to build the marsh (Anderson and Race 1980).

Another wetland type associated with the coast is the "transitional marsh" which forms when sea water invades low-lying coastal freshwater wetlands (Kelley et al. 1988) (Figure 12). A description of wetland communities associated with this process and locations in the Acadia region is provided in Chapter 6.

WETLAND HYDROLOGY

The special characteristics associated with plants and soils in wetland habitats derive largely from their relationship with water. Water—the duration and pattern of its presence, the history of its travels recorded in its chemistry, and its role as a vehicle for transport of materials (seeds, sediment)—is the major player in the formation and maintenance of wetlands. The diversity of wetland ecosystems, from the ombrotrophic acid peatlands in the northeastern United States to the highly productive, nutrient-rich bottomland hardwood forested wetlands of the southeastern United States, aside from climatic influences, is largely shaped by hydrology and water regimes—the timing and duration of saturated and/or flooded conditions. Sources of hydrologic inputs (groundwater, surface water, precipitation, runoff from uplands, tidal), as well as water losses (outlets, groundwater recharge, evapotranspiration) are determined by hydrogeologic setting, and often dictate water regimes. The nature of the wetland community, be it microbial, invertebrate, vertebrate, or plant, reflects the relationship of water with the landscape in general—its topography, geology, landuse history, and its soils.

The USFWS's wetland classification system (Cowardin et al. 1979) includes water regime[3] modifiers to describe hydrologic characteristics. Two groups of water regimes are identified: (1) tidal and (2) nontidal. Tidal water regimes are driven by oceanic tides, while nontidal regimes are largely influenced by surface water runoff and groundwater discharge. A list of water regime modifiers used by the USFWS and their definitions (Cowardin et al. 1979) appears in Table 2.

In general, water tables fluctuate markedly during the year. From winter to midspring or early summer, the water table is at or near the surface in many wetlands. During this time, water may pond or flood the wetland for variable periods. In May or June, the water table may begin to drop, usually reaching its low point between late August and October. Longer days, increasing air temperatures, increasing evapotranspiration, and other factors are responsible for the consistent lowering of the water table from spring through summer.

Table 9. Examples of plant indicators of water regimes for the Acadia region's nontidal wetlands.

Water Regime	Indicator Plants
Permanently Flooded	*Nymphaea odorata* (white water lily) *Nuphar variegatum* (spatterdock) *Potamogeton* spp. (pondweeds) *Nymphoides cordata* (floating heart)
Semipermanently Flooded	*Sparganium* spp. (burreeds) *Juncus militaris* (bayonet rush) *Pontedaria cordata* (pickerelweed) *Sagittaria latifolia* (common arrowhead) *Eriocaulon septangulare* (common pipewort)
Seasonally Flooded	*Typha latifolia* (broad-leaved cattail) *Carex stricta* (tussock sedge) *Dryopteris thelypteris* (marsh fern) *Nemopanthus mucronata* (mountain holly) *Viburnum cassinoides* (wild raisin) *Acer rubrum* (red maple)
Saturated/ Seasonally Saturated	*Sarracenia purpurea* (pitcher plant) *Rhyncospora alba* (white beak-rush) *Chamaedaphne calyculata* (leatherleaf) *Sphagnum* spp. (Sphagnum moss)

Tidal Wetland Hydrology

In coastal areas, oceanic tides are the dominant hydrologic feature of marine, estuarine, and tidal fresh wetlands. Along the Atlantic coast, tides are semidiurnal with a period of 12 hours and 25 minutes. There are two high tides and two low tides each day. Since the tides are largely controlled by the position of the moon relative to the sun, the highest high tides and lowest low tides usually occur during full and new moons (spring tides). Neap tides, or tides of decreased range, also occur semimonthly when the moon is in quadrature (i.e., first quarter and third quarter). Coastal storms can also cause extreme high and low tides. Strong winds over a prolonged period have a great impact on the mean tidal range in coastal bays. Table 7 shows examples of varying tidal ranges in the Acadia region.

[3]Water regime should not be confused with hydrogeologic setting; it is used here in accordance with Cowardin et al. (1979) to describe duration and frequency of flooding/saturation in a wetland during the growing season (the frost-free period) and does not in all cases lend insight into hydrologic budgets, sources of water, or surficial geology.

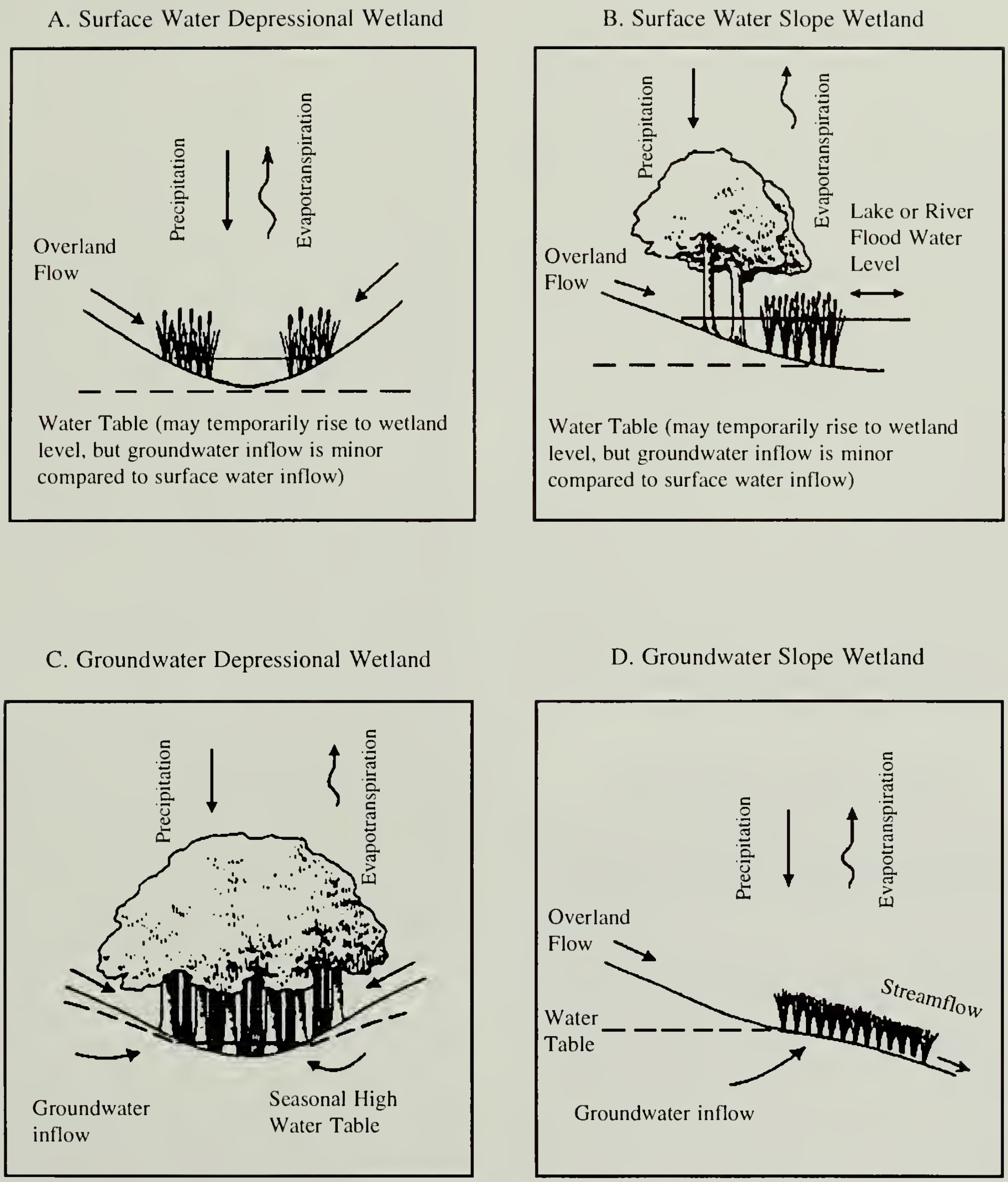

Figure 14. Hydrology of surface (A & B) and groundwater (C & D) wetlands (Tiner 1989).

Marine wetlands include the spray or irregularly flooded zone of the rocky shore down to the subtidal regimes which lie below the extreme low tide point. Bluegreen algal communities are commonly associated with the uppermost zone. Aquatic beds dominated by plants, including the rockweeds (*Fucus* and *Ascophyllum*) and kelp (*Laminaria*), are found in the middle and lower intertidal areas, which are flooded and exposed by the tides at least once daily (Cowardin et al. 1979), and in subtidal regimes (zonation patterns are discussed in Chapter 6).

In estuarine wetlands (salt marshes, intertidal flats), differences in hydrology (tidal flooding) create two readily identifiable zones: (1) the regularly flooded zone and (2) the irregularly flooded zone (Figure 13). The regularly flooded zone is alternately flooded and exposed at least once daily by the tides. It includes both "low marsh" (regularly flooded salt marsh) and intertidal mud and sand flats. Above the regularly flooded zone, the salt marsh is less frequently inundated by the tides (less than once a day). This irregularly flooded zone, or "high marsh," is typically flooded for brief periods particularly during spring and neap tides and storm events. Estuarine plants have adapted to these differences in hydrology (Nixon 1982; Teal 1986) and may be good indicators of water regime (Table 8). In the Acadia region, subtidal and low intertidal regimes may support aquatic beds dominated by eel grass (*Zostera*) and widgeon grass (*Ruppia*).

In addition to tides it should be noted that estuarine wetlands may be influenced by other hydrologic inputs including groundwater discharge, surface runoff, and freshwater inputs from streams.

Tidal fresh wetlands are subject to fluctuation in water levels because of the influence of oceanic tides on fresh streams that drain into estuaries. However, tidal range in freshwater tidal wetlands on MDI are generally quite reduced (<0.5 meters) due to frictional attenuation of tides along shallow, winding stream courses.

Nontidal Wetland Hydrology

The hydrology of nontidal wetlands is more complex than that of tidal wetlands because landscape position (relationship to regional water tables, condition and topographic features of the associated watershed), soil characteristics (texture, water infiltration rate, structure, presence of restrictive layers), and proximity to other wetlands and deepwater habitats have a major role in determining hydrologic regime. Also to aptly describe the hydrologic characteristics of a wetland, a detailed knowledge of the duration and timing of surface inundation, both yearly and long-term, along with an understanding of water table activity, is required (Cowardin et al. 1979).

Given these constraints, a discussion of nontidal wetland hydrology is best framed in conceptual models of hydrogeologic settings with examples being approximations of the general concepts. The hydrology of the Acadia region's wetlands fits into a conceptual model developed by Novitzki (1982) for describing the hydrogeologic settings of Wisconsin wetlands. Figure 14 shows these four hydrogeologic settings: surface water depressional; surface water slope; groundwater depressional; and groundwater slope. The settings are defined by dominant hydrologic inputs and outputs. Each wetland setting is discussed below as applicable to the wetlands of the Acadia region. Table 9 provides some plant indicators of nontidal water regimes.

Hydrogeologic settings

Surface water depressional wetlands

Major hydrologic inputs to surface water depressional wetlands are overland flow and precipitation. Often these wetlands are referred to as "perched" wetlands because they occupy a position above the regional water table. Water from overland runoff and precipitation may be perched on a confining layer of clay or compact till, creating conditions conducive to wetland development. Common wetland classes found in surface water depressional settings are forested and scrub-shrub communities. The water table can fluctuate dramatically and rapidly during the growing season. Water regimes commonly associated with this hydrogeologic setting in the region include temporarily flooded, seasonally flooded, and in the raised bogs, seasonally saturated/saturated regimes.

Surface slope wetlands

In surface slope wetlands, the hydrologic inputs most important in maintaining the wetland are surface water inputs such as lake or river flood waters and overland flow. Although groundwater may contribute to inputs during some time of the year, this input is not essential to the character of the wetland. Surface slope wetlands include lake and river floodplains. The greatest flooding occurs in winter and early spring. Major flooding is frequently associated with frozen soil, snowmelt, and/or spring rains. This wetland type is not extensive in the Acadia region as many of the wetlands adjacent to the region's major streams and lakes are largely supported by seasonally high groundwater. Isolated instances of wetlands maintained largely through stream and lake flooding may occur, but were not observed by the investigators.

Typical New England forested floodplain communities dominated by maples, elms, and ashes do not occur in the Acadia region. Rather, wet meadows and shrub swamps are likely to develop in these settings. In general, extensive freshwater wetlands maintained solely by flooding phenomenon are not typical of the region.

Groundwater depressional wetlands

Hydrology in groundwater depressional wetlands is controlled by water table activity. Groundwater depressional wetlands develop in low-lying positions in the landscape and generally maintain wetland hydrology through interception of the regional water table. In the Acadia region, these wetlands occur in till, bedrock, and glaciomarine landscapes. Often groundwater depressional wetlands in till develop organic soils and may support various classes of wetlands including forested and scrub-shrub wetlands. In fact the majority of the depressional wetlands in glaciomarine deposits fit into this category. Glaciomarine sediments in the valleys between the mountains and in low-lying coastal regions (southwestern ANP) generally intercept regional groundwater tables. Usually areas that intercept the regional water table stay saturated for longer periods during the growing season than surface water wetlands.

Groundwater slope wetlands

Groundwater slope wetlands occur in landscapes where the water table intersects the surface of a slope or hillside. It may be a till slope perching a local water table that pops out at various places along the slope, or it may be a regional groundwater table seeping out of fluvial deposits. Commonly referred to as hillside seeps or seepage wetlands, these occur in the Acadia region and may support both hardwood and softwood forests. They are quite common on some of the smaller islands surrounding MDI, including Isle au Haut. Standing water is uncommon although small depressions along the slope may temporarily hold water. On the foggy, cool islands around MDI, some slopes as steep as 15% may accumulate seasonally saturated organic deposits.

Alteration of wetland hydrology

Human influences

Human influences on wetland hydrology are readily observed in the Acadia region, such as roads dissecting wetlands and altering the exchange of water. At Mitchell Cove, for example, a road culvert still allows tidal waters to inundate areas upstream of the road, but the natural hydrology is altered sufficiently to result in plant community changes (Roman et al. 1984; Clark 1977). Some wetland areas are drained or filled in an attempt to create more useable space for farming or building. Often ponds are dug in existing wetland or spring areas, altering the ecology and classification of the natural wetland. Ditching (salt marshes), quarrying, and gravel mining may have altered the wetland ecology of the region to some extent.

Influence of beaver

As beaver dam stream outlets, they change the hydrology of the area behind the dam, either creating a wetland from an upland or changing the water regime of an existing wetland. Long-term inundation of both upland and wetland forests kills the trees. If the area were a forested wetland, it could change to a wetter class such as shrub swamp, wet meadow, or aquatic bed depending on depth and duration of flooding. Similarly, flooded uplands will succeed to wetland communities, the class depending on depth and duration of flooding. When the beaver exhaust their food resources, they move on, leaving the area to drain and slowly succeed to drier wetland classes (forested) or upland. Sediments in some drainageways tell stories of repeated beaver activity evidenced by organic soils layered with mineral alluvium horizons (e.g., the small tributary of Canon Brook, to the southeast of Dorr Mountain). Gilmore Meadow, thickly layered with organic materials, is maintained as a wet meadow through the activity of beaver. Other examples can be seen east of the Precipice. (See Chapter 6 for examples of beaver-maintained wetlands and Chapter 8 for further discussion of the role of beaver in the Acadia region.)

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CHAPTER 5. THE HYDRIC SOILS OF ACADIA NATIONAL PARK AND VICINITY

INTRODUCTION

Most wetland communities evolve on a substrate of hydric soils. Hydric soils have a variety of properties caused by regular saturation or inundation by water. The moisture status of hydric soils, determined by local climate and hydrology, enables them to support an array of vegetative communities, from those best adapted to life in saturated soils to those that can only tolerate wetness of seasonal duration. This chapter defines hydric soils, discusses some of their important properties as well as differences among them, and describes the hydric soils of the Acadia region.

DEFINITION OF HYDRIC SOIL

The Soil Conservation Service (SCS) (1987) defines a hydric soil as a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic (i.e., oxygen depleted) conditions in the upper part. Hydric soils develop under conditions wet enough to support the growth and regeneration of hydrophytic vegetation.

In general, soils that have a water table within 15 centimeters of the mineral soil surface long enough during the growing season to create anaerobic conditions are classified as hydric. In Maine, this would include poorly and very poorly drained soils. Somewhat poorly drained soils are not hydric unless they meet the flooding and ponding criteria. Table 10 lists the definitions of these drainage classes (Soil Survey Staff 1951).

HYDRIC SOIL CHARACTERISTICS

Important morphological characteristics of hydric soils can be attributed to the duration and depth of saturation. Qualities of soil water also affect soil chemistry and composition. Soils that are saturated most of the year, or that are saturated several times a day by fluctuating tide waters, can accumulate several meters of organic materials. Under wet conditions plant communities contribute organic materials to the soil surface faster than they can be oxidized or decomposed and removed from the soil mass.

The hydric soils of the Acadia region belong to the frigid soil temperature regime. The mean annual temperature in the frigid soil profile is less than 8°C. The difference between mean summer and mean winter soil temperatures is more than 5°C at a depth of 50 centimeters (Soil Survey Staff 1992).

Organic Soils

A simplified rule says that in a wetland situation, a soil is classified as organic (Histosol) if more than half of the upper 80 centimeters (32 inches) is composed of materials having more than 20% organic matter by weight (12% organic carbon) (Soil Survey Staff 1975).

The degree of humification (decay of plant remains to amorphous organic matter) (Damman and French 1987) of an organic soil and the types of plant materials it contains depend both on its hydrology and on the history of plant community development at the soil surface. The history of plant communities can be interpreted from plant remains through pollen and macrofossil analyses (Davis et al. 1975; Patterson et al. 1983).

Sapric soil materials, or mucks, are highly decomposed and humified organic materials. Undisturbed sapric materials retain less than one-third identifiable plant particles by volume. Organic soils that have decomposed to this degree are often found in contact with mineral-rich drainage waters or in forested depressional areas that receive nutrients from groundwater. Well-decomposed organic soils are common in the study area and are associated with forest, shrub fen, and emergent/shrub fen communities.

Hemic soil materials, or mucky peats, are organic materials that have decomposed to an intermediate degree. Undisturbed hemic materials contain one-third to two-thirds identifiable plant particles by volume. Mucky peats often occur in areas of changing hydrology that have only relatively recently experienced an increased rate of decomposition.

Fibric soil materials, or peats, are organic materials that have decomposed to the least degree. Undisturbed fibric materials retain about two-thirds identifiable plant particles by volume. In this region, sphagnum moss makes up most of the identifiable particles. Fibrists are found in ombrotrophic raised bogs, such as Big Heath, that receive water and nutrients strictly from the atmosphere.

Table 10. Definitions of soil drainage classes.

Drainage Class	Definition
Very Poorly Drained	Water drains from the soil very slowly. The water table is at or near the mineral soil surface from October through early July. During wet summers, or in the lowest positions, the water table may remain near the surface during July, August, and September. (Commonly, very poorly drained soils occur in concave bottomlands and may be underlain by a restrictive layer. On coastal islands and exposed headlands that receive ample atmospheric moisture, very poorly drained soils can occur on seepage slopes with restrictive layers.)
Poorly Drained	Water drains from the soil very slowly. A water table is within 18 cm of the mineral soil surface during October, November, and December and again from April into June. The water table rises into this zone following heavy rains during the summer months and during winter thaws. (Commonly, poorly drained soils have a restrictive layer and occur on low slopes. The may occupy concave bottomlands with no restrictive layer. On coastal islands and exposed headlands that receive ample atmospheric moisture, poorly drained soils can occur on seepage slopes with a restrictive layer.)
Somewhat Poorly Drained	Water drains from the soil slowly. A water table is between 18 and 40 cm below the mineral soil surface during wet Octobers and during November, April, and May. The water table rises into this zone following heavy rains during the growing season and during late fall and winter thaws. The soil may be saturated close to the surface during November and April. (Commonly, somewhat poorly drained soils have a restrictive layer and occur on low slopes. They may occur in low-lying positions with no restrictive layer.)
Moderately Well Drained	Water drains from the soil somewhat slowly. A water table is between 40 and 100 cm from the mineral soil surface during wet Novembers and during April and the first part of May. The soil may be saturated closer to the surface for brief periods in November and April. (Commonly, moderately well drained soils have a restrictive layer and occur on moderate slopes, or have no restrictive layer and occur in low-lying positions.)
Well Drained	Water drains freely and no seasonally high water table develops within 100 cm of the mineral soil surface. The soil retains available moisture during the growing season. (Commonly, well drained soils have loamy textures and no restrictive layer. They may have a restrictive layer and occur on steep slopes.)

Source: from Soil Survey Staff (1951) and compiled by the author from regional field observations and consultation with SCS soil scientists.

Mineral Soils

Mineral hydric soils have properties associated with wetness, but do not accumulate enough plant material to be classified as organic. Morphological characteristics of hydric mineral soils can be very important in distinguishing wetlands from adjacent uplands and in interpreting local hydrology.

The two most widely recognized features that reflect wetness in mineral soils are gleying and mottling (Tiner and Veneman 1987). Currently, the terms "iron-depleted matrix" and "iron depletions" are applied to these soil features (Vepraskas 1992). When soils become saturated, flooded, or ponded for extended periods during which the soil is above about 5°C, molecular oxygen in soil water is used by soil bacteria, and the soil develops under anaerobic conditions. Eventually, iron and manganese compounds are reduced and mobilized by soil microbes when adequate energy sources (i.e., organic particles) are available (Veneman et al. 1976). Mineral soils in positions that intercept the regional groundwater table and are saturated for prolonged periods can become gleyed (i.e., have iron-depleted matrices). The gleization process results in gray, bluish gray, and greenish gray colors in the soil as iron and manganese are reduced and removed from it (Tiner and Veneman 1987). Bright, oxidized zones can occur in gleyed soils along oxidized root channels (Vepraskas 1992).

Commonly, the water table fluctuates within the soil profile, and the surface layers are alternately saturated and drained, producing "drainage mottles" (i.e., iron depletions). The soil matrix usually ranges from shades of brown to olive grays. Lighter spots of grey colors form under saturated conditions as soil bacteria, associated with particles of organic carbon, use the oxygen combined with iron and manganese. Reduced iron and manganese are soluble and move outward from the zone of depletion (Vepraskas 1992). As the water table drops and the soil becomes aerated, a rind develops around the depleted spots in which metallic ions are again oxidized to exhibit bright colors. Small, firm, irregularly shaped nodules and concretions may also develop in saturated soils (Soil Survey Staff 1992). They are believed to form when air quickly penetrates a soil, perhaps into soil zones containing reduced iron and manganese (Vepraskas 1992).

The color of the soil matrix, as well as the quantity, size, distribution, and strength of expression of iron depletions, reveal important clues about the duration and frequency of saturation of various soil layers. Iron depletions may persist after a soil has been artificially drained, highlighting areas that were hydric under natural conditions.

Organic materials may mask iron depletions in organic-rich surface horizons. Tilling or disturbing the soil surface may also destroy iron depletion patterns. Oxidized root channels can provide an important clue to soil wetness in these situations. On some saturated slopes, water may move through soil surface horizons, surfacing at slope breaks as springs. In such situations, soil water may remain aerated, and anaerobic conditions may not prevail. These areas deserve further study as they can be quite wet, but are not currently classified as hydric soils.

HYDRIC SOILS IN THE LANDSCAPE

Figure 15 shows an idealized cross section of the Acadian landscape and the positions of hydric soils within it.

During the last period of deglaciation, the ocean fingered between the mountains along the southern, southeastern, and eastern coastline, depositing narrow bands of glaciomarine sediments. Hydric soils have formed in these low areas and in till deposits blanketing other low areas such as Black Woods and Sargent Brook valleys.

A low core of mountains in the center of the western lobe is joined around its margins by glacial tills and by glaciomarine sediments ranging from fine silty clays to coarser sands and gravels (see Chapter 4). The lower and flatter areas have formed large complexes of hydric soils, with sizeable areas of organic soils occurring in the very lowest positions.

HYDRIC SOIL DESCRIPTIONS

This section describes the most common hydric soils in the Acadia region. Table 11 shows the relationships among hydric soils, their parent materials, and classifications. The soils described below represent central concepts portraying the hydric soils of the region and by no means characterize the complete array of soil properties observable in wetlands. For materials and methods and for detailed soil descriptions, please refer to Appendix 1.

Wetland classifications were more dependent on hydrogeologic setting than on specific soil characteristics. Only Ipswich and Waskish soils form in conjunction with the specific plant community types they support, as determined by their unique settings (i.e., salt marsh and peatland, respectively).

Tidal Marsh Soils

Ipswich soils

The Ipswich soils are very poorly drained organic soils that form in estuaries and tidal marshes where the energy level of the salt water is low enough that sediments can accumulate to keep pace with rising sea levels (Anderson and Race 1980). The surfaces of these areas are almost level, with slightly depressed pannes, and are dominated by grasses, sedges, and rushes.

Typically, Ipswich soils have a 24-centimeter surface layer of very dark brown mucky peat of herbaceous origin, bound and woven with roots and rhizomes. The surface is underlain by dark reddish brown muck to a depth of 130 centimeters or more. A sulfur, or "rotten egg," odor is apparent throughout the soil.

Ipswich soils are saturated by tidal water twice daily throughout the year, but are only flooded above the surface during storms or astronomically high tides. Towards the fringes of tidal marshes, close to small bedrock islands, and in smaller tidal marsh areas, organic materials less than 130 centimeters thick overlie bedrock, glacial till materials, or glaciomarine sediments.

The Ipswich soils of the Acadia region have a colder average soil temperature (less than 8°C) as well as a greater degree of decomposition than the Ipswich series established in Massachusetts (USDA Soil Conservation Service [A] 1986). Ipswich and similar soils can be found associated with salt marsh communities in Mitchell Cove and Bass Harbor Marsh northwest of Adams Bridge. Shallow organic deposits occur in small tidal marshes on Schoodic Peninsula behind the barrier beach northwest of Moose Island, in Mosquito Harbor on Isle au Haut, and along Northeast Creek south of Route 3 on MDI.

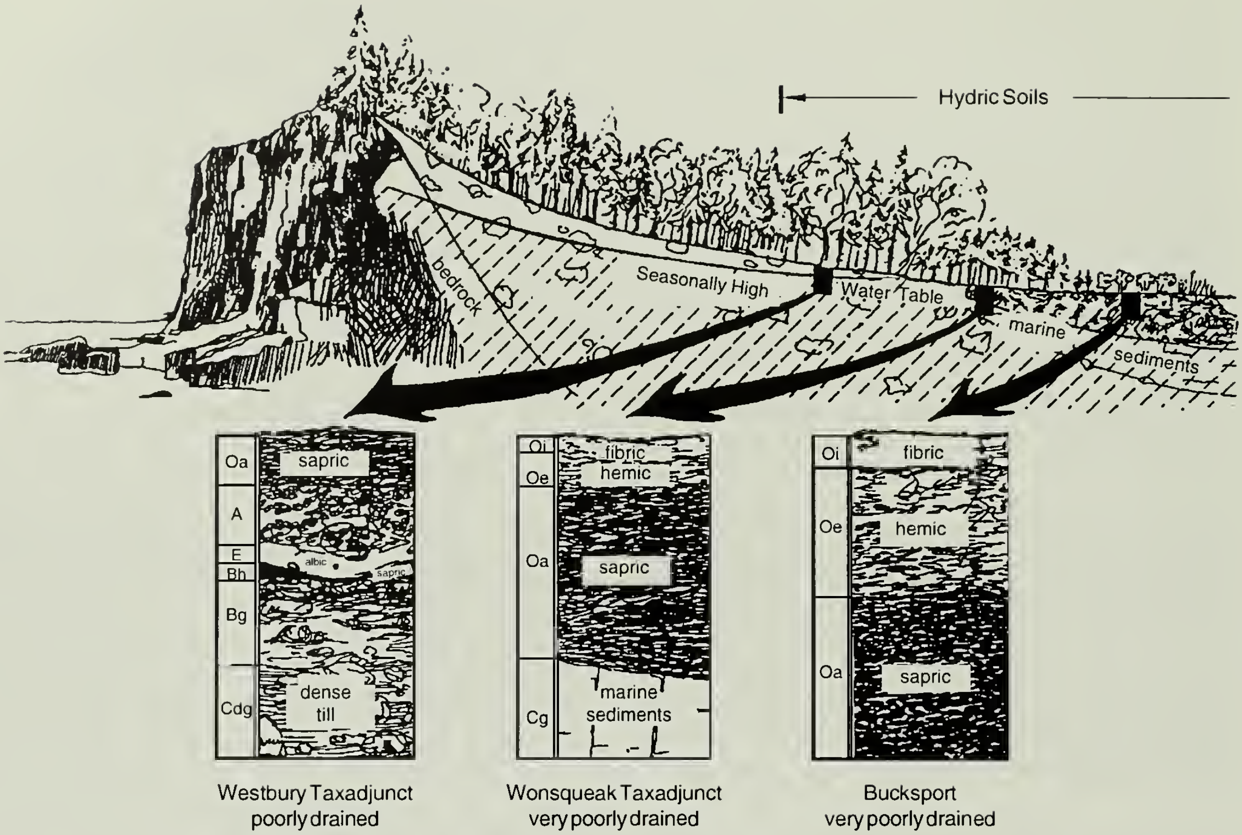

Figure 15. Idealized cross section of the Acadian landscape and the positions of hydric soils (drawn by J.E. Cormier).

Fresh Water Organic Soils

Waskish soils

The Waskish soils are very poorly drained organic soils composed almost entirely of slightly decomposed sphagnum moss. They are associated with raised peat bogs with characteristic ericaceous- and sphagnum-dominated vegetation communities. The surface is characterized by cradle-and-mound microrelief with Waskish soils occupying both positions (areas with cradle-and-mound microrelief have undulating soil surfaces of concave swales and convex humps).

Typically, Waskish soils are composed of dark reddish brown sphagnum peat to a depth of at least 160 centimeters. The soil is extremely acid throughout (pH less than 4.5).

The water table is at or near the surface from approximately November into July in these soils (USDA Soil Conservation Service [B] 1988). Water moves through and fluctuates in the upper layers of the peat where most of the biological activity occurs. Below the level of lowest water in July and August, the peat remains permanently saturated, little water movement takes place, and biological activity is very low (Damman and French 1987). Waskish soils are not widespread in the study area.

Waskish soils can be found associated with scrub-shrub communities on Big Heath and The Heath of Great Cranberry Isle (R. Davis, University of Maine, pers. comm.).

Bucksport soils

The Bucksport soils are very poorly drained, well-decomposed organic soils with very deep organic materials. They are usually found in flat areas adjacent to freshwater streams and in nearly level low-lying areas on glaciomarine sediments or glacial till. The soil surface is usually dominated by sphagnum moss and is characterized by cradle-and-mound microrelief, with Bucksport soils occupying both positions.

Typically, they have a 37-centimeter surface layer of very dusky red and dark reddish brown peat of woody and herbaceous origin. Be-

Table 11. Hydric soil chart: Relationships of parent material, drainage class, soil series and classification.

Parent Material and Selected Characteristics	Poorly Drained	Very Poorly Drained
A. ORGANIC SOILS - pH		
1. Saprists, Tidal area soils		IPSWICH TAXADJUNCT (euic, frigid Typic Sulfisaprist)
2. Fibrists, pH <4.5		WASKISH (dysic, frigid Typic Sphagnofibrist)
3. Saprists, non-tidal area soils		
(a) typic soils (organic layers more than 130 cm thick) pH >4.5		BUCKSPORT (euic, Typic Borosaprist)
(b) terric soils (mineral layers encountered between 40 and 130 cm below the organic surface) pH >4.5		WONSQUEAK (loamy, mixed, euic, Terric Borosaprist)
B. SOILS IN WATER-SORTED MATERIALS (glaciomarine, glaciolacustrine, and glaciofluvial)		
1. fine silty soils formed in silt and clay over loamy materials		BIDDEFORD TAXADJUNCT (fine-loamy, mixed, nonacid, frigid, Histic Humaquept)
2. sandy soils		SEARSPORT (sandy, mixed, frigid, Histic
Humaquept)		
C. SOILS IN GLACIAL TILL	WESTBURY TAXADJUNCT (coarse-loamy, mixed, frigid, Typic Epiaquod)	PEACHAM (coarse-loamy, mixed, nonacid, frigid, Histic Humaquept)

Source: Modified from USDA Soil Conservation Service 1990a.

low the surface, the soil is composed of dark reddish brown, dark brown, and very dark brown muck to a depth of at least 130 centimeters.

The water table is at or near the surface usually from September into July (USDA Soil Conservation Service [B] 1992), and water stands on the surface of the cradles during the spring and fall. During very wet summers, the water table may stay near the surface in August.

Bucksport and similar soils are very common in the study area. They can be found associated with a scrub-shrub fen fringing an area along Adams Brook over a kilometer upstream from Adams Bridge, associated with an emergent/ scrub-shrub fen community along Aunt Betsy's Brook in Fresh Meadow, as well as with a hardwood forested wetland west of the Sieur de Monts Spring parking area.

Wonsqueak soils

Wonsqueak soils are very poorly drained, well-decomposed organic soils that overlie mineral materials within 130 centimeters. They are in depressions in glacial till, outwash landscapes in postglacial sediment basins, or in the fringe areas of large, multiple-unit peatlands. The surface is usually characterized by weakly expressed cradle-and-mound microrelief.

Typically, Wonsqueak soils have a 20-centimeter surface layer of very dark gray muck of dominantly herbaceous origin containing 5% mineral material. The subsurface, to 81 centimeters, is black muck of dominantly herbaceous origin. The substratum, to 165 centimeters, is gray silt loam (USDA Soil Conservation Service [A] 1992).

The water table is at or near the surface usually from September into July (USDA Soil Conservation Service [B] 1991). During very wet summers, the water table may stay near the surface in August. Soils similar to Wonsqueak soils, but which have mineral substrata of heavy silty clays, are found in low-lying areas containing glaciomarine sediments. In other areas containing sandier sediments or tills, soils similar to Wonsqueak soils overlie sandy or sandy loam substrata.

Wonsqueak and similar soils are relatively common in the study area and can be found associated with an evergreen forested wetland near upper Hadlock Pond, a scrub-shrub fen on the western shoreline of Schoodic Peninsula, and a black spruce forested wetland west of Route 102 on the north end of MDI.

Soils in Water-Sorted Materials

Biddeford soils

Biddeford soils are very poorly drained mineral soils that formed in heavy glaciomarine sediments. They are found in low-lying areas that were flooded by ocean waters as the last glacier receded. Surfaces may be level or have well-developed cradle-and-mound microrelief, with Biddeford soils occupying both positions.

Typically, Biddeford soils have a 7-centimeter surface layer of black mucky peat underlain by black muck to a depth of 33 centimeters. The subsoil is gray and very dark gray silty clay loam to 100 centimeters, and dark bluish gray clay loam to 110 centimeters. The substratum, from 110 to 140 centimeters, is greenish gray loam.

The water table is at or near the surface usually from October into July (USDA Soil Conservation Service [B] 1992), but may persist in August and September in wet summers.

The Biddeford soils in the MDI area differ from the "Biddeford Series" established in York County, Maine, because they have a fine loamy particle size class, with more sand and less clay in the lower strata. Soils in some low, flat areas have very thin clay-rich subsoils overlying loamy or sandy deposits. In most low, postglacially marine-inundated areas (e.g., west of Jones Marsh and northeast of Big Heath) heavy glaciomarine sediments are less than 1 meter thick over till or sandy sediment layers. By contrast, thick (3–4 meters), heavy sediment deposits underlie sand in somewhat higher positions at the back of small coves or small valley drainages (e.g., Compass Harbor, Hunters Brook) (T. Lowell, University of Ohio, pers. comm.). The marine environment of the MDI area during the regional deglaciation period is not well understood.

Biddeford and similar soils are not widespread in the study area. However, examples can be found in an evergreen forested wetland northeast of Adams Bridge near the NPS boundary and in a mixed forested wetland southeast of the Hio Road north of Seawall campground.

Searsport soils

The Searsport soils are very poorly drained mineral soils that formed in thick sandy deposits. Searsport soils are found in depressions in or below glacial outwash deltas and on lower slopes of outwash terraces that receive significant runoff. Areas of Searsport soils have formed in glaciomarine sediments laid down in environments of intermediate energy. Surfaces are nearly level to gently sloping and usually have weakly expressed cradle-and-mound microrelief.

Typically, Searsport soils have a 4-centimeter surface horizon of dark yellowish brown peat. The subsurface (to 22 centimeters) is very dark brown muck. The subsoil is composed of 10 centimeters of very dark and dark brown sandy loam. The substratum, from 32 to 130 centimeters, grades from gray to dark grayish brown sand. From 130 to 155 centimeters, the substratum is dark gray loamy sand.

The water table is at or near the surface usually from September into July (USDA Soil Conservation Service [B] 1985).

Searsport and similar soils are not widespread in the study area, but can be found associated with a hardwood swamp in a glaciomarine sediment basin north of the Route 102 Town Hill intersection, a hardwood swamp east of Seal Harbor Village on the south side of Route 3 in a depressional area below outwash deposits, and a scrub-shrub fen south of the Dodge Point Road on western MDI.

Glacial Till Soils

Westbury soils

The Westbury soils are poorly drained mineral soils with relatively thin organic surfaces that formed in glacial till. These soils are usually found on forested lower slopes of glacial till landscapes and on low mounds in depressional areas and poorly defined drainageways in glacial till landscapes characterized by cradle-and-mound microrelief.

Typically, Westbury soils have a 12-centimeter surface layer of black muck. The subsurface, to 25 centimeters, is black and very dark gray, very cobbly fine sandy loam. The subsoil, between 25 and 29 centimeters, is mottled, gray gravelly sandy loam. Below this, to 33 centimeters, the subsoil is dark brown gravelly fine sandy loam, grading into mottled, grayish brown gravelly fine sandy loam with pockets of sandy loam to 52 centimeters. The substratum is firm, mottled olive gray gravelly fine sandy loam below 52 centimeters.

Note that these soils have well-developed dark brown spodic horizons underlying a mottled albic horizon. Such a horizon usually develops when a water table fluctuates frequently through porous materials and is not usually characteristic of soils with a firm basal till layer. The occurrence of these morphological characteristics in compact glacial till also has been noted in the International Paper Company experimental forest in Howland, Maine (USDA Soil Conservation Service 1990b). Water table fluctuation and soil development are poorly understood in these wetland areas.

Westbury soils in this area differ from the "Westbury Series" established in Wayne County, N.Y. In this region they are poorly drained rather than somewhat poorly drained, having a water table periodically within 15 centimeters of the mineral soil surface from October until December and from March until June. In some years the water table fluctuates throughout the winter months or during the summer. Soils similar to Westbury soils, but containing more silt and clay and lacking spodic horizons, occur adjacent to low-lying areas of glaciomarine sediments.

Westbury and similar soils are common in the study area. They can be found associated with a mixed disturbed forested wetland east of the Pretty Marsh picnic area road in a depression in a glacial till upland, an evergreen forested wetland south of the Blackwoods Campground access road on a toe slope of a basal till upland, and an evergreen forested wetland on the eastern part of Schoodic Peninsula in a flat-bottomed depression in a glacial till landscape.

Peacham soils

The Peacham soils are very poorly drained mineral soils, with organic surfaces between 20 and 40 centimeters thick. Peacham soils are usually found in depressions and poorly defined drainageways in glacial till landscapes. Often, Peacham soils are found in the cradles left by the windthrow of trees that dominate nearly level lodgement till landscapes. Lodgement, or basal till, refers to dense till materials laid down and compacted by the glacial ice.

Typically, Peacham soils have a 9-centimeter surface layer of dark yellowish brown peat, composed mostly of sphagnum fibers. The subsurface layer is dark reddish brown muck from 9 to 29 centimeters. Below this is an 11-centimeter-thick layer of black and very dark brown, organically enriched gravelly sandy loam, overlying 5 centimeters of mottled dark grayish brown gravelly silt loam. The substratum consists of firm, mottled, dark grayish brown gravelly fine sandy loam.

The water table is at or near the surface usually from October into June (USDA Soil Conservation Service [B] 1985).

Peacham and similar soils are relatively common in the study area. They can be found associated with a scrub-shrub community east of Route 102 near the Pretty Marsh picnic area road, an evergreen forested wetland south of Mosquito Cove on Isle au Haut, and an evergreen forested wetland south of the Hill Road near the Little Echo Lake road.

HYDRIC SOILS ON THE ISLANDS

On islands smaller than MDI, such as Isle au Haut and the Cranberry Isles, and on narrow land masses exposed to the sea on three sides, such as Schoodic Peninsula, the soils exhibit important properties that differ from MDI and mainland soils.

On these smaller islands and exposed headlands, hydric soils are found on steeper slopes and in higher positions than in more protected situations. Organic matter accumulates to greater depths than would be expected in areas of similar landscape position and hydrology on MDI and the mainland. These areas tend to exhibit thick, organically enriched mineral subsurface horizons on very poorly to somewhat poorly drained soils. Occasionally organically enriched subsurfaces occur even on moderately well drained soils.

The smaller islands and exposed peninsulas have annual temperatures moderated by their proximity to the ocean. Winter air temperatures are warmer than further inland, and temperatures in the summer warm slowly, sometimes only reaching 20°C on Mt. Desert Rock by the end of July (J. Carlisle, University of Maine, pers. comm.). Winds warmer than Gulf of Maine water blow from the southwest through south about 50% of the time during the summer, resulting in frequent fogs (Patterson et al. 1983). Cooler summers favor the accumulation of organic materials. Coastal fogs may be an important factor in keeping island soils moister throughout the growing season.

Climatic and soil differences between the islands and the more protected areas warrant further investigation. Establishing relationships between hydrology, plant communities, soil profile characteristics, and climatic variables could further the process of protection of water resources in coastal areas.

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Plate 1. Marine aquatic bed. Note algal zonation related to tidal exposure.

Plate 2. An example of a wetland complex including Marine, Estuarine, and Palustrine systems at Sand Beach, ANP.

Plate 3. Salt marsh at Bass Harbor. An estuarine emergent wetland exhibiting high primary production and providing nursery areas for a diversity of marine organisms.

Plate 4. Beaver meadow near Witchhole Pond. An example of a palustrine emergent wetland resulting from inundation of a forested wetland by beaver.

Plate 5. An example of a palustrine scrub-shrub wetland dominated by leatherleaf.

Plate 6. Big Heath, ANP. An example of a rare peatland type, a raised coastal plateau bog.

Plate 7. An example of a poorly drained hydric soil (Westbury) in the Blackwoods area, ANP.

Plate 8. *Arethusa bulbosa,* a rare orchid found in peatlands.

Plate 9. Northeast Creek, a riverine wetland complex including submerged aquatic beds as well as adjacent palustrine wetlands.

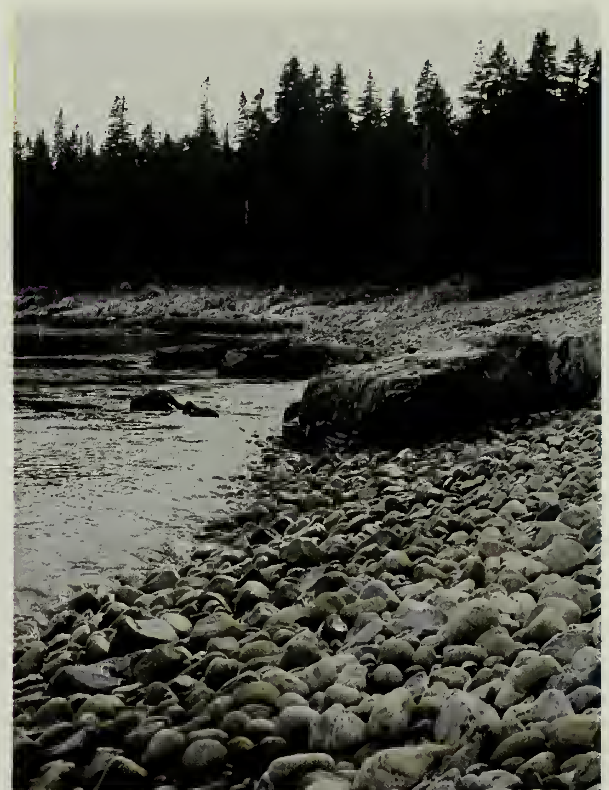


Plate 10. An example of a marine intertidal unconsolidated shore on Isle au Haut.

CHAPTER 6. WETLAND PLANT COMMUNITIES

INTRODUCTION

Wetlands, traditionally known as marshes, swamps, bogs, and fens, are classified according to the dominant vegetation community for purposes of regulation, habitat evaluation, inventory, and management. The classification system developed by the USFWS (Cowardin et al. 1979) and used by NWI recognizes five ecological systems: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. All five systems are represented in the Acadia region. The purpose of this chapter is to describe the major wetland plant communities (classes) in each of these systems. A complete list of wetland plants recorded in the region for this project can be found in Appendix 2, while plant species associated with the major wetland communities of the Acadia region are found in Table 12.

Factors Influencing Wetland Plant Community Development

The structure and floristic composition of wetlands are determined by complex interactions among many environmental variables. These include climate; abiotic factors such as soil properties, both physical and chemical, water chemistry, and hydrology; biotic factors such as insect infestation, plant disease, plant competition, and the activity of beaver; anthropogenic influences including water level manipulation (construction projects, reservoirs, drainage ditches, channelization), silviculture, agriculture, and peat mining; and large-scale phenomenon including fire, major storms, and rising sea level.

The wetland plant communities of the Acadia region are diverse in structure and species composition owing to many of the above factors, with the most important being hydrogeologic settings (Chapter 4), human disturbance (logging and development), fire history, and beaver activity.

WETLAND COMMUNITIES

Marine System

The Marine System consists of the open ocean overlying the continental shelf and its associated high-energy shoreline. Water regimes are determined primarily by the tidal action and salinities exceeding 30 parts per thousand (Cowardin et al. 1979) (Figure 16). This system is well represented in the region. The rugged rocky shoreline and its associated algal beds and tidal pools, boulder and cobble beaches, and isolated pockets of sand beach, constitute the marine wetlands which attract so many visitors to the Acadia region.

Aquatic beds

Algal beds and the flora associated with the splash zone represent the only vegetated wetland class in the Marine System. MDI, Schoodic Peninsula, and the associated smaller islands provide an outstanding variety of substrates for macroalgal community development, including granite ledges, large boulders, cobble beaches, and rare sand bottoms. Tide pools are particularly abundant along the coastline.

Distinct vertical zonation is a universal characteristic of the marine macroalgae community (Lewis 1964). Many factors, including wave energy and site exposure, tidal range, substrate texture, slope, irradiance, and grazing pressure, appear important to defining this zonal distribution (e.g., Harlin and Lindbergh 1977; Mathieson 1979; Lubchencho 1980; Dawes 1981; Topinka et al. 1981).

Despite the extensive rocky intertidal and subtidal environments of the region, there have been few published studies focusing on zonation patterns, except for earlier works of Johnson and Skutch (1928a, b, and c). However, several unpublished marine algal surveys (see Greene et al. 1992) and a comprehensive flora listing 125 marine algae species (Greene et al. 1992) enable a reasonable description of marine algae zonation in the study area. Comprehensive studies of vertical algal distribution patterns along New Hampshire and southern Maine coasts, also dominated by coldwater marine algae taxa, do exist (Mathieson 1979; Mathieson et al. 1981).

In the Acadia region, the supra-intertidal zone, commonly called the spray or black zone, is generally dominated by cyanobacteria (*Calothrix* spp.) and lichens along with patches of the red alga *Bangia atropurpurea*. In the upper to lower intertidal zone, the richness of macroalgal species dramatically increases. The brown algae (Phaeophyta) *Fucus spiralis* is often at the upper limit of this zone. The brown rockweeds, *Ascophyllum nodosum* and *Fucus vesiculosus,* are particularly abundant in the intertidal zone—a characteristic of the entire rocky coastline of New England (Taylor 1957). Species more common at the upper to mid-intertidal zone may include the green (Chlorophyta) filamentous, *Ulothrix flacca*, along with the brown *Petalonia* sp. and *Scytosiphon lomentaria*. Irish moss (*Chondrus crispus*), *Gigartina stellata*, a red

Table 12. Characteristic wetland plant communities in Acadia National Park and vicinity.

AQUATIC BED/FRESHWATER MARSH

Nymphaea odorata (white water lily)
Juncus militaris (bayonet rush)
Juncus canadensis (Canada rush)
Scirpus validus (soft-stem bulrush)
Scirpus cyperinus (wool grass)
Carex stricta (tussock sedge)
Carex oligosperma (few-seeded sedge)
Calamagrostis canadensis (blue-joint grass)
Typha latifolia (broad-leaved cattail)
Nuphar variegatum (spatterdock)
Nymphoides cordata (floating hearts)
Eriocaulon septangulare (common pipewort)
Potamageton spp. (pondweeds)
Sparganium spp. (burreeds)
Pontedaria cordata (pickerelweed)
Sagittaria latifolia (common arrowhead)
Utricularia purpurea (purple bladderwort)
Juncus effusus (soft rush)

SALT MARSH

Spartina alterniflora (smooth cordgrass)
Spartina patens (saltmarsh hay)
Spartina pectinata (giant cordgrass)
Juncus gerardii (blackgrass)
Juncus balticus (baltic rush)
Juncus filiformis (thread rush)
Festuca rubra (red fescue)
Agrostis alba var. *palustris* (creeping bent grass)
Agrostis stolonifera (bent grass)
Agropyron repens (quackgrass)
Scirpus maritimus (saltmarsh bulrush)
Eleocharis palustris (saltmarsh spikerush)
Carex viridula (little green sedge)
Cyperus filicinus (slender flat sedge)
Plantago oliganthos ((seaside plantain)
Glaux maritima (sea milkwort)
Triglochin maritima (seaside arrow grass)
Solidago sempervirens (seaside goldenrod)
Salicornia europaea ((common glasswort)
Limonium nashii (sea lavendar)
Ruppia maritima (widgeon grass)
Potentilla anserina (silverweed)
Aster subulatus (annual saltmarsh aster)
Atriplex patula (marsh orach)
Carex paleacea (chaffy sedge)

EMERGENT PEATLAND

Carex exilis (coast sedge)
Carex lasiocarpa (wooly-fruit sedge)
Carex oligosperma (few-seeded sedge)
Carex paupercula (poor sedge)
Scirpus cyperinus (woolgrass)
Scirpus cespitosus (tufted bulrush)
Eriophorum spp. (cotton grass)
Rhyncospora alba (white beakrush)
Juncus canadensis (Canada rush)
Drosera rotundifolia (round-leaved sundew)
Sarracenia purpurea (pitcher plant)
Chamaedaphne calyculata (leatherleaf)
Vaccinium macrocarpon (large cranberry)
Sphagnum spp. (sphagnum moss)

SHRUB PEATLAND

Larix laricina (larch)
Picea mariana (black spruce)
Ledum groenlandicum (Labrador tea)
Acer rubrum (red maple)
Rhododendron canadense (rhodora)
Kalmia angustifolia (sheep laurel)
Kalmia polifolia (bog laurel)
Andromeda glaucophylla (bog rosemary)
Gaylussacia dumosa (dwarf huckleberry)
Gaylussacia baccata (black huckleberry)
Chamaedaphne calyculata (leatherleaf)
Juniperus communis (creeping juniper)
Vaccinium oxycoccus (small leaf cranberry)
Vaccinium macrocarpon (large cranberry)
Empetrum nigrum (black crowberry)
Rubus chamaemorus (baked apple-berry)
Rhyncospora alba (white beaked rush)
Scirpus cespitosus (tufted bulrush)
Carex exilis (coast sedge)
Carex lasiocarpa (slender sedge)
Carex oligosperma (few-seeded sedge)
Cladium mariscoides (smooth sawgrass)
Eriophorum virginicum (tawny cotton grass)
Eriophorum tenellum (delicate cotton grass)
Eriophorum spissum (Hare's tail cotton grass)
Eriophorum angustifolium (narrow-leaved cotton grass)
Xyris caroliniana (yellow-eyed grass)
Arethusa bulbosa (Arethusa)
Calopogon pulchellus (grass pink)
Pogonia ophioglossoides (rose pogonia)
Sarracenia purpurea (pitcher plant)
Drosera rotundifolia (round-leaved sundew)
Drosera intermedia (spatulate-leaved sundew)
Utricularia cornuta (horned bladderwort)
Utricularia vulgaris (common bladderwort)
Aster nemoralis (bog aster)
Solidago uliginosa (bog goldenrod)
Symplocarpus foetidus (skunk cabbage)
Smilacina trifolia (false Solomon's seal)

FORESTED WETLAND

Evergreen forested wetlands
Dominant canopy species
Thuja occidentalis (Northern white cedar)
Picea rubens (red spruce)
Picea mariana (black spruce)

Subordinate canopy species
Larix laricina (larch)
Acer rubrum (red maple)
Populus tremuloides (quaking aspen)
Betula papyrifera (white birch)

Shrub species
Amelanchier spp. (serviceberry)
Ilex verticillata (winterberry)
Alnus rugosa (speckled alder)
Alnus crispa (green alder)
Vaccinium corymbosum (highbush blueberry)
Viburnum cassinoides (wild raisin)
Spiraea latifolia (meadowsweet)
Nemopanthus mucronata (mountain holly)

Table 12 Cont.

Evergreen forested wetlands
Shrub species cont.
- *Kalmia angustifolia* (sheep laurel)
- *Vaccinium angustifolium* (low sweet blueberry)
- *Myrica gale* (sweetgale)
- *Gaylussacia baccata* (black huckleberry)
- *Ledum groenlandicum* (Labrador tea)
- *Chamaedaphne calyculata* (leatherleaf)

Herbs and ground cover species
- *Symplocarpus foetidus* (skunk cabbage)
- *Cornus canadensis* (bunchberry)
- *Maianthemum canadense* (Canada mayflower)
- *Trientalis borealis* (starflower)
- *Linnaea borealis* (twinflower)
- *Coptis groenlandica* (goldthread)
- *Rubus hispidus* (swamp dewberry)
- *Gaultheria hispidula* (creeping snowberry)
- *Vaccinium macrocarpon* (large-leaved cranberry)
- *Carex trisperma* (three-seeded sedge)
- *Osmunda cinnamomea* (cinnamon fern)
- *Sphagnum* spp. (sphagnum moss)

Deciduous forested wetlands
Dominant canopy species
- *Acer rubrum* (red maple)
- *Betula papyrifera* (white birch)
- *Populus tremuloides* (quaking aspen)

Subordinate canopy species
- *Abies balsamea* (balsam fir)
- *Picea rubens* (red spruce)
- *Thuja occidentalis* (northern white cedar)
- *Betula alleghaniensis* (yellow birch)
- *Betula populifolia* (grey birch)
- *Pinus strobus* (white pine)

Shrubs species
- *Ilex verticillata* (winterberry)
- *Alnus rugosa* (speckled alder)
- *Alnus crispa* (green alder)
- *Vaccinium corymbosum* (highbush blueberry)
- *Corylus cornuta* (beaked hazelnut)
- *Prunus serotina* (black cherry)
- *Vaccinium angustifolium* (lowbush blueberry)
- *Kalmia angustifolia* (sheep laurel)
- *Spiraea latifolia* (meadowsweet)
- *Viburnum cassinoides* (wild raisin)
- *Nemopanthus mucronata* (mountain holly)
- *Picea* spp. (spruce)
- *Abies balsamea* (balsam fir)
- *Acer rubrum* (red maple)
- *Myrica gale* (sweetgale)
- *Gaylussacia baccata* (black huckleberry)

Herbs and ground cover species
- *Onoclea sensibilis* (senstive fern)
- *Dryopteris noveboracensis* (New York Fern)
- *Osmunda cinnomomea* (cinnamon fern)
- *O. claytonia* (interrupted fern)
- *Glyceria* spp. (manna grass)
- *Carex trisperma* (three-seeded sedge)
- *C. intumescens* (bladder sedge)
- *Calamagrostis canadensis* (blue-joint grass)
- *Arisaema trifolia* (Jack-in-the-pulpit)
- *Aster* spp. (asters)
- *Solidago* spp. (goldenrods)
- *Maianthemum canadense* (Canada mayflower)
- *Smilacina trifoliata* (false Solomon's seal)

MARINE ROCKY SHORE

Supra-intertidal zone
- *Calothrix* spp. (cyanobacteria)
- *Bangia atropurpurea* (red algae)

Intertidal zone
- *Fucus spiralis* (brown algae)
- *Ascophyllum nodosum* (brown rockweed)
- *Fucus vesiculosus* (brown rockweed)
- *Chondrus crispus* (Irish moss)
- *Ulva lactuca* (green sea lettuce)

Tide pools
- *Enteromorpha* spp. (green algae)
- *Fucus distichus* (rockweed)
- *Palmaria palmata* (dulse)

Subtidal
- *Laminaria digitata* (kelp)
- *Laminaria saccharina* (kelp)
- *Laminaria longicruris* (kelp)
- *Agarum cribrosum* (kelp)
- *Palmaria palmata* (dulse)
- *Chondrus crispus* (Irish moss)

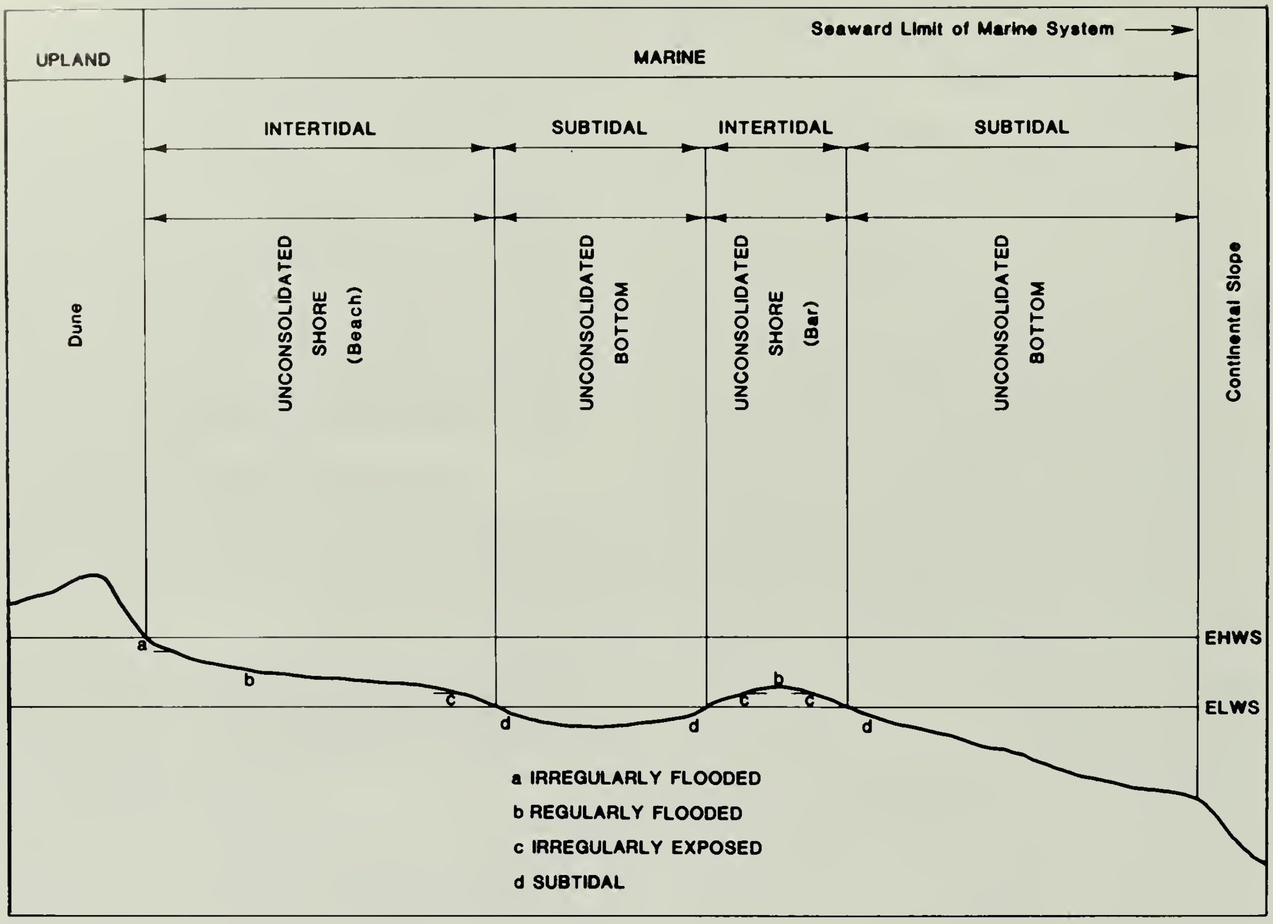


Figure 16. Distinguishing features and examples of habitats in the Marine System. EWHS = extreme high water of spring tides; ELWS = extreme low water of spring tides (Cowardin et al. 1979).

alga much like *Chondrus* in appearance, and the green sea lettuce (*Ulva lactuca*) are generally near mean low water (i.e., low intertidal zone). The encrusting *Hildenbrandia rubra* is quite common and forms thin reddish-brown patches covering rocks of the mid- to low intertidal zone. In the same zone, the easily recognized red alga, *Corallina officinalis*, with small, calcified, often brittle branches, occurs. Tide pools in the rocky intertidal zone share many of the above-mentioned species, along with a host of others, including the green *Enteromorpha* spp. (most notably *E. intestinalis* and *E. linza*), *Fucus distichus*, and the red alga dulse (*Palmaria palmata*).

The subtidal zone is dominated by the kelps and red algae. The brown blades of the kelps (*Laminaria digitata, L. saccharina, L. longicruris*) are most conspicuous, along with *Agarum cribrosum*, a kelp with numerous holes in the blade. Some of the red algae common to the subtidal zone include *Ceramium rubrum*, *Phyllophora* sp., *Palmaria palmata*, and *Chondrus crispus*. At sites in southern Maine and New Hampshire, the lower limits of the subtidal zone (to 30 meters below mean low water) are dominated by tuft (e.g., *Polysiphiona urceolata*), crustose (e.g., *Lithothamnium* spp.), and foliose-fleshy red algae (*Polysiphonia nigrescens*) (Mathieson 1979). The structure of this deep, light-limited zone is very unlike the lush kelp beds often associated with the shallower subtidal zone.

Otter Point, along the ANP Loop Road, is perhaps one of the more accessible locations to observe the rocky intertidal algal community along a fairly steep gradient (i.e., compressed intertidal zone). Extensive tide pools also are present here at low tide. At Seawall and Wonderland, along the most southeastern shore of MDI, the gradient is gradual with a broad intertidal zone dominated by the rockweeds. At these latter sites, boulders, cobble, and rock outcrop substrates are in sharp contrast to the steep granite ledges that characterize Otter Point.

Estuarine System

The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land, but have constant or sporadic access to the open ocean, and in which. ocean water is at least occasionally diluted by freshwater runoff. The landward limit of the Estuarine System extends upstream and landward to where ocean-derived salts measure less than 0.5 parts per thousand during the period of average annual low flow (Cowardin et al. 1979) (Figure 17). The Estuarine System is represented in the Acadia region by intertidal mud flats, rocky shores, salt marshes, and aquatic beds, with the most abundant intertidal environments being mud flats, coarse gravel flats, and exposed rock (Kelley et al. 1988). The most extensive salt marshes in Acadia are associated with the major streams (fluvial-minor marshes) of Bass Harbor Marsh, Fresh Meadow, and Pretty Marsh, while less extensive salt marshes and flats develop in the many protected embayments, coves, and harbors associated with the jagged coastline.

Intertidal flats (unconsolidated bottom)

Given the high tidal range of MDI and vicinity (over 3 meters), intertidal flats are extremely common and extensive features of the estuarine environment. Mud flats are the most common unconsolidated intertidal bottom type in the study area, yet occasional sand flats also occur. Intertidal mud flats are most pronounced within relatively protected areas where suspended sediments (mostly silt, with some fine sand and clay intermixed) are deposited (Fefer and Schettig 1980). Over the long term, mud flats are depositional environments responding to a rising sea level, but when considered on a seasonal or even daily time frame, they are geologic environments undergoing periodic episodes of both deposition and erosion (Anderson et al. 1981). Natural processes such as tidal currents, wind-generated waves, ice

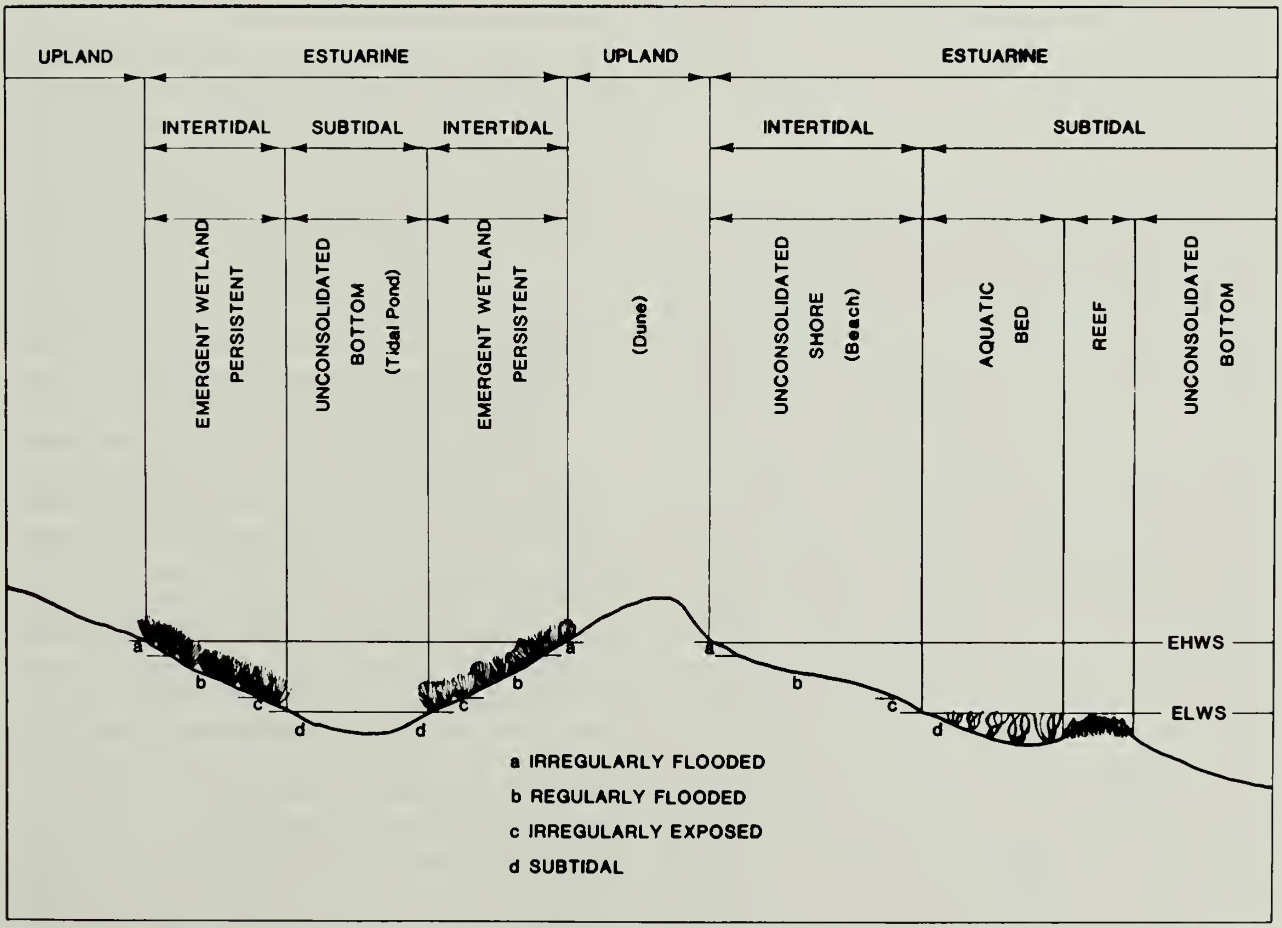


Figure 17. Distinguishing features and examples of habitats in the Estuarine System. EWHS = extreme high water of spring tides; ELWS = extreme low water of spring tides (Cowardin et al. 1979).

scouring, and bioturbation tend to control this dynamic bottom.

Mud flats support a rich microalgal community, particularly dominated by benthic diatoms (Whitlatch 1982), but stable substrate suitable for attachment of macroalgae is generally lacking, aside from an occasional rock or shell. However, sparse patches of drift algae (e.g., *Ulva lactuca*, *Enteromorpha* spp.) are often found on mud flats; yet to the casual observer the extensive intertidal mud flats of the study area appear devoid of vegetation. It is noted that in eastern coastal Maine (Cobscook Bay region), dense algal mats (primarily *Enteromorpha intestinalis*) have been observed on intertidal mud flats (Vadas and Beal 1987). The cause of these macroalgal blooms remains unclear.

Ecologically and economically the intertidal mud flats of MDI and vicinity are extremely valuable. Fefer and Schettig (1980) provide an excellent overview of the diverse invertebrate populations of coastal Maine mud flats and their critical importance to shorebirds, gulls, wading birds, and waterfowl. Commercial harvest of soft-shelled clams (*Mya arenaria*) and bait worms (sand worm—*Nereis virens*) is particularly prevalent on intertidal mud flats of the area.

Estuarine aquatic beds

Subtidal beds of submerged aquatic macrophytes (actually submerged flowering plants or angiosperms), dominated by eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*), are found throughout the study area. Geographically, eelgrass is found along the East Coast of North America from the Carolinas to Nova Scotia, growing in shallow, relatively protected waters of 10 to 30 parts per thousand salinity (Thayer et al. 1984). Locally, in MDI and vicinity, eelgrass beds predominate toward the higher end of this salinity range. Especially lush eelgrass meadows are found on muddy subtidal substrates along the northern shores of MDI (i.e., Mount Desert Narrows, Eastern Bay). To date, no comprehensive studies of eelgrass communities in the Acadia region have been conducted; however, studies elsewhere in New England address the role of eelgrass in supporting estuarine detritus-based food webs (Roman and Able 1988; Thayer et al. 1984), as well as the nursery or habitat function for estuarine-dependent fin and shellfisheries (Heck et al. 1989).

Eelgrass wasting disease reportedly devastated eelgrass populations along the Atlantic coast of North America in the 1930s (Short et al. 1988). The disease, thought to be caused by a slime-mold-like pathogenic strain of *Labyrinthula* (Short et al. 1987), and subsequent decline in eelgrass beds were reported responsible for reductions in commercial fisheries harvests and waterfowl populations (see Thayer et al. 1984). Wasting disease is recurring on the East Coast, including Maine, yet epidemic conditions (i.e., complete dieoff) as in the 1930s are not reported (Short et al. 1988).

The submerged aquatic *Ruppia maritima* generally occurs in areas of lower salinity, from 5–25 parts per thousand (Verhoeven 1980). The subtidal creeks of Bass Harbor Marsh and Adams Creek support particularly dense populations of widgeon grass. Studies are currently underway to evaluate the primary productivity dynamics (Zubricki 1992) and ecological function of this habitat in Bass Harbor Marsh (C.T. Roman, National Park Service, pers. comm.). In terms of wildlife support, it is widely recognized that both widgeon grass and eelgrass meadows provide ideal feeding habitat for herbivorous birds, particularly waterfowl (Thayer et al. 1984).

Estuarine emergent wetlands

Historically, the extent and distribution of salt marshes, or emergent estuarine wetlands, in Maine has been underestimated. Although more than two-thirds (68%) of the total area (79 km^2) of salt marsh occurs southwest of Penobscot Bay, more individual marshes occur within and northeast of the Penobscot Bay region (Jacobson et al. 1987). A survey by Jacobson et al. (1987), conducted to document the extent and geographic distribution of salt marshes in Maine, found that Maine has more salt marsh area than any other New England state or the Bay of Fundy region.

Despite the importance of this ecosystem, published descriptions of salt marsh communities in Maine are very limited (Jacobson and Jacobson 1989; Jacobson et al. 1987; Kelley et al. 1988). Nixon's (1982) description of the ecology of the high salt marshes in New England relies heavily on data from southern New England. Nixon mentions that Maine has more high marsh than low marsh (11:1), yet provides no detailed descriptions. Similarly, Teal's (1986) work on the ecology of the low salt marsh community in New England focuses on marshes in southern New England. Salt marsh communities in southern Maine (e.g., Wells Marsh and Scarborough Marsh) are similar to those in southern New England; however, the marshes north and east of Penobscot Bay are typified by a different vegetation community, which is described below. These differences can be attributed to geomorphological settings (see Chapter 4), tidal amplitude, and climate.

Salt marsh communities occur in three major areas in the Acadia region: (1) along tidal streams (such as those associated with Bass Harbor Marsh and Fresh Meadow); (2) along the various embayments, harbors, and coves along the convoluted rocky coast (e.g., Bass Harbor, Mitchell Cove, Thomas Bay, Pretty Marsh Harbor, Ponds Island Cove on Schoodic Peninsula); and (3) as fringe marshes along tidal creeks with relatively steep slopes or relatively high-energy coastlines (e.g., Mount Desert Narrows, Mosquito Harbor on Schoodic Peninsula, Merchant's Cove, Isle au Haut). The most common salt marsh communities in the region—fluvial minor marshes, fringe marshes, and transitional marshes—are described below.

Tidal stream or fluvial minor salt marshes

The largest salt marsh complexes (e.g., Bass Harbor Marsh, 22 hectares) occur along tidal streams and are associated with Ipswich and related soil series. The distinct vegetation zonation in some marshes in southern Maine and typical of southern New England salt marshes (depicted in Figure 18) is rare in these marshes. Mudflats grading into a regularly flooded low marsh (flooded semi-diurnally) dominated by tall-form salt marsh cordgrass (*Spartina alterniflora*) (3–6 meters)—typical of southern New England marshes—is replaced by a mixture of plants including blackgrass (*Juncus gerardii*), red fescue (*Festuca rubra* L.), creeping bent grass (*Agrostis gigantea Roth.*), and baltic rush (*Juncus balticus*). Less common plants in this zone include seaside arrow grass (*Triglochin maritima*), silverweed (*Potentilla anserina*), seaside goldenrod (*Solidago sempivirens*), and thread rush (*Juncus filiformis*) (reported in Bass Harbor Marsh, Linda Gregory, National Park Service, pers. comm.). A well-developed *Spartina alterniflora* zone is absent, but a narrow zone occurs along small tidal creeks and in discontinuous strips along stream channels.

The transition between the regularly flooded marsh and the irregularly flooded marsh in the Acadia region is indistinct. In southern New England marshes, this change in hydrology and other abiotic factors is marked by a transition from a predominantly *Spartina alterniflora* community to one dominated by saltmarsh hay (*S. patens*). The high marsh-low marsh distinction is obscured in the Acadia region as many species found in the regularly flooded zone also occur in the irregularly flooded zone, including black grass, red fescue, creeping bent grass, and baltic rush.

Within the high marsh environment, assemblages of species vary spatially, forming a mosaic of communities reflecting subtle differences in hydrology, substrate hydraulic conductivity, salinity, soil oxygen tension, nutrients, freshwater input, and disturbance history (wrack deposition, ice-rafting, mowing/grazing) (Niering and Warren 1980) as well as stochastic events (Miller and Egler 1950). The high marsh zone has little slope (<1% slope), but is characterized by an uneven surface of gentle mounds, depressions, and salt pannes resulting in a highly variable microtopography. Common plants occurring in mixed communities include *Spartina patens*, quackgrass (*Agropyron repens*), *Agrostis alba* var. *palustris, Juncus gerardii, Triglochin maritima,* and *Juncus balticus*. Monotypic patches of *J. gerardii* or *J. balticus* are common. Often they occur in slight depressions in the high marsh plain. Other species occasionally occurring in the high marsh zone include seaside plantain (*Plantago oliganthos*), sea-milkwort (*Glaux maritima*), sea lavender (*Limonium nashii*), tall sea blite (*Suaeda linearis*), blue-joint (*Calamagrostis canadensis*), sweet grass (*Hierchloe odorata*), hairgrass (*Deschampsia flexuosa*) hoary sedge (*Carex canescens*), and marsh-straw sedge (*C. hormathodes*). Fox-tail barley (*Hordeum jubatum*) and Virginia wild rye (*Elymus virginicus*), generally associated with upland habitats, have been noted in some of the marshes, most likely the result of river- or animal-transported seed propagules.

Salt marsh pannes are common in the high marsh zone, which is generally saturated, particularly at high tide. Much speculation has been generated as to their development. Theories include (1) dead bare spots resulting from prolonged deposition of flotsam; (2) erosion and ice scouring (Niering and Warren 1980) or depression from ice-rafting; (3) decay of underlying peat because of poor drainage giving rise to potholes (Nixon 1982); or (4) blockage of drainage creeks by slumping of the banks (Nixon 1982). Panne morphology ranges from shallow, vegetated muddy depressions to deep pools which may support macroalgae and other aquatic plants of high wildlife value including widgeon grass (*Ruppia maritima*), as well as mosquito larvae, and fish assemblages (*Fundulus* spp. and others). The panne is a harsh environment which, because of its irregular flooding re-

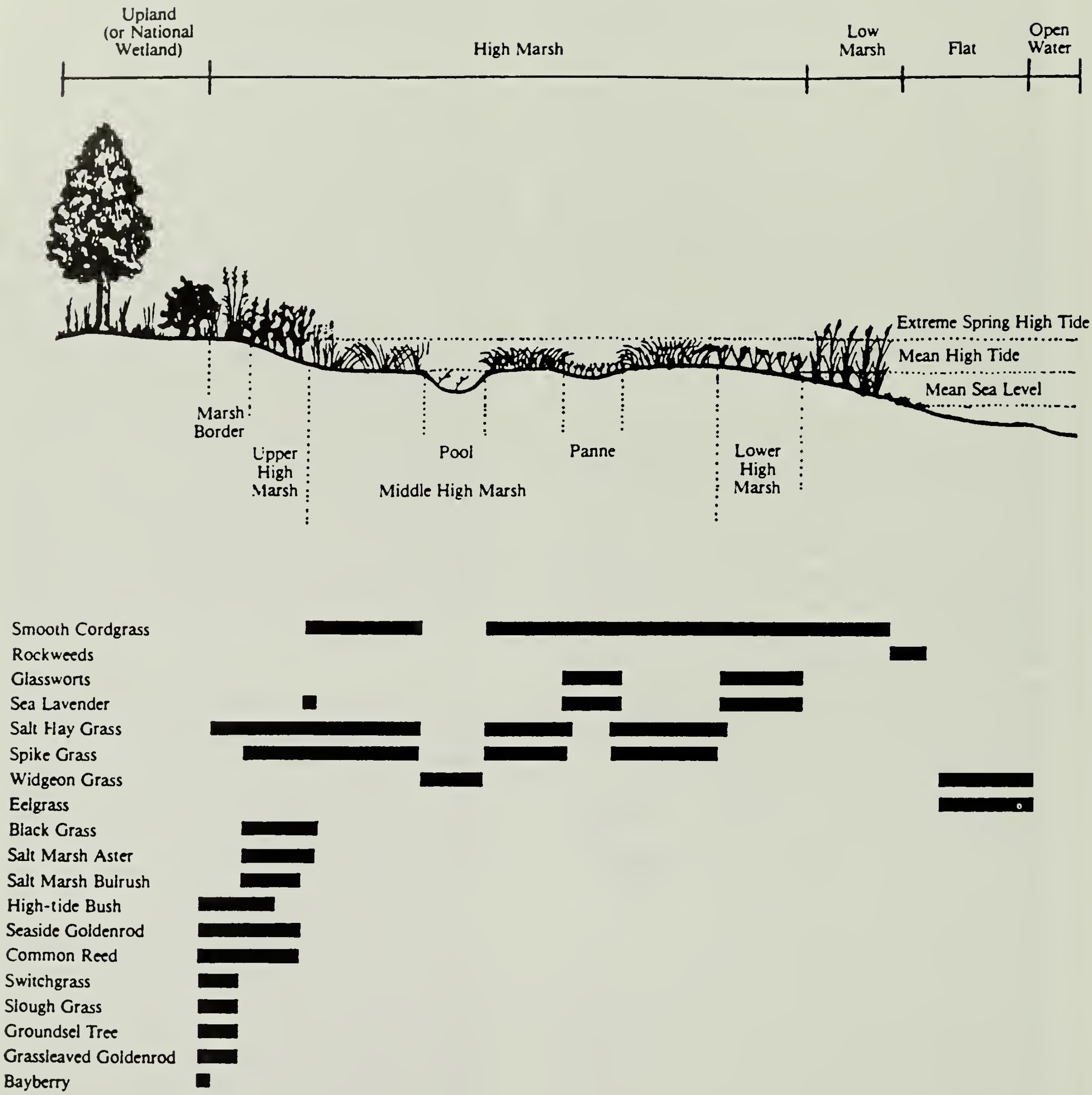


Figure 18. Generalized plant zonation in southern New England salt marshes: (1) low marsh and (2) high marsh. The high marsh can be further divided into several subzones. Note that plant diversity increases toward upland (Source: adapted from Tiner 1987).

gime, is subject to dramatic changes in both temperature and salinity. The panne may become very fresh after rain events, or much more saline than seawater following dry periods or between flooding events. For this reason, the plants that colonize pannes must tolerate extremes in moisture content, temperature, and water and soil chemistry (Niering and Warren 1980). Pannes closer to the stream channels are shallow, muddy depressions typically colonized by common glasswort (*Salicornia europaea*) and *Triglochin maritima.* Pannes toward the upland edge, flooded less regularly by seawater, receive freshwater inputs from adjacent wetlands, springs, or runoff from the upland. Often these pannes are dominated by one species such as little green sedge (*Carex viridula*), saltmarsh spikerush (*Eleocharis palustris*), *Triglochin maritima,* slender flatsedge (*Cyperus filicinus*), or saltmarsh bulrush (*Scirpus maritimus*) (often in pools of standing water). Less common are *Spartina alterniflora* (short form), *Solidago sempervirens*, marsh orach (*Atriplex patula*), annual saltmarsh aster (*Aster subulatus*), and New York aster (*A. novi-belgii*). Well-developed pannes are found in Bass Harbor Marsh west of Route 102. Common salt marsh plants are presented in Table 12.

The transition zone between the high marsh and freshwater wetlands or upland habitats is characterized by high species diversity. This zone, depending on microrelief, adjacent plant communities, and topography, is a patchwork of salt tolerant freshwater species and salt marsh species. Again, this community does not form a distinct zone dominated by one species, but rather varies in species composition, density, and distribution from marsh to marsh. Low shrubs encountered in this zone include steeplebush (*Spirea tomentosa*), meadowsweet (*Spirea latifolia*), black chokeberry (*Aronia melanocarpa*), bayberry (*Myrica pensylvanica*), swamp rose (*Rosa nitida*), and sweet gale (*Myrica gale*). Herbs include chaffy sedge (*Carex paleacea*), slough grass (*Spartina pectinata*), curled dock (*Rumex crispus*), goldenrods (*Solidago* spp.), *Calamagrostis canadensis*, *Eleocharis palustris, Potentilla anserina*, *Juncus balticus,* marsh St. Johnswort (*Hypericum virginicum*), *Aster* spp. (including flat-top white aster, *A. umbellatus*), and narrow-leaved cattail (*Typha angustifolia*). These plants are also found along the brackish or tidal fresh stretches of streams associated with salt marshes. Lower Bass Harbor Marsh, parts of Fresh Meadow, and Pretty Marsh are good examples of salt marsh communities in the Acadia region.

Several species of rare plants occur in the salt marsh habitat. American sea-blite (*Suaeda americana*) and Rich's sea-blite (*S. richii*) have historic records in the Acadia region, but no locations are currently known (Greene 1990). Gaspe arrow-grass (*Triglochin gaspense*), found below the high-tide line of salt marshes, could occur in salt marshes on Schoodic Peninsula, but a site is not currently known.

It is interesting to note that many salt marshes in New England and along the coastal plain of the mid- and southeastern United States coast have been ditched to drain the irregularly flooded marsh in an effort to reduce mosquito populations (Bourn and Cottam 1950; Provost 1977). Mosquito ditches in the marshes of the Acadia region have not been maintained for several years and are beginning to fill with vegetation and sediment. However, they are still clearly visible in the marsh landscape (e.g., Bass Harbor Marsh near Adams Bridge). Many studies on the response of marsh vegetation patterns to ditching are found in southern New England and elsewhere (see Niering and Warren 1980).

Fringe salt marshes

Salt marshes associated with steeply sloping coves, embayments, or tidal channels are typically low in species diversity and form fringe marshes or narrow bands of low marsh. *Spartina alterniflora* and *Salicornia europaea* are the dominant plants, with *Limonium nashii* and *Triglochin maritima* being subordinate. A narrow zone of *Spartina patens, Solidago sempervirens,* and *Juncus gerardii* may or may not occur at the upland edge depending on the slope and substrate characteristics of the stream channel. Good examples of fringe marshes can be seen between Thompson Island and MDI along the Mt. Desert Narrows, in Merchant's Cove and Deep Cove on Isle au Haut, and as one enters ANP on Schoodic Peninsula (near Mosquito Harbor). These fringing marshes are generally from <1 meters to 30 meters wide.

Transitional marshes

Kelley et al. (1988) recognize a transitional salt marsh which typically develops when a glacial deposit that surrounds a bog is eroded, draining the bog and allowing invasion by the sea or when low, flat freshwater wetlands are inundated by salt water as a function of rising sea level. In the Acadia region, bogs often occur adjacent to the fluvial minor salt marsh complexes. As sea level rises at a rate of approximately 3 mm/yr (Kelley et al. 1988), the occurrence of salt marsh invading freshwater peatlands may be more common. This phenomenon may be occurring in a few of the salt marshes inventoried—Bass Harbor Marsh, Jones Marsh, and to the east of the one-way road entering ANP on Schoodic Peninsula (located northeast of Moose Island). A thin transition zone shared by typical bog species, including leatherleaf (*Chamaedaphne calyculata*), large-leaved cranberry (*Vaccinium macrocarpon*), narrow-leaved cotton grass (*Eriophorum angustifolium*), and sphagnum mosses (*Sphagnum* spp.), and salt marsh species, including *Spartina patens, S. alterniflora, S. pectinata, Triglochin maritima, Juncus balticus,* and *Solidago sempervirens,* was observed.

Regional perspective

As in southern New England (Miller and Egler 1950; Niering and Warren 1980), the salt marshes of Acadia are dominated by the high marsh community. The classic zonation pattern (Figure 18) (i.e., from mudflat to low marsh dominated by *Spartina alterniflora* to high marsh dominated by *S. patens* with a landward zone of *Juncus gerardii*) is more distinct in southern New England and southern Maine (Jacobson and Jacobson 1989) than in the Acadia region. In southern New England, however, *Spartina patens* may occur in pure stands or be codominant with spike grass (*Distichlis spicata*) (Tiner 1989), a species uncommon in the Acadia region. In the Acadia region, the high marsh zone has a higher diversity of grasses, sedges, and rushes than that reported for other New England marshes (Nixon 1982; Niering and Warren 1980). Upper-border species common in southern New England, including hightide bush (*Iva frutescens*), switchgrass (*Panicum virgatum*), groundsel trees (*Baccharis halimifolia*), red cedar (*Juniperus virginiana*), and in disturbed areas, common reed (*Phragmites australis*) (Niering and Warren 1980; personal observation), are absent in these marshes.

Zonation patterns in the Acadia region's marshes are similar to marshes in the Bay of Fundy region. Pielous and Routledge (1976) studied changes in salt marsh vegetation patterns as a function of latitude in Canadian salt marshes from latitudes 44°40' N to 58°50' N. They noted that, along the southeast shore of Nova Scotia, marshes typically display four vegetation zones dominated respectively by *Spartina alterniflora, S. patens, Carex paleacea,* and *Juncus balticus.* Although pure zones were not seen in the Acadia region's marshes, the species listed in these zones were consistently present.

Study of salt marsh community development, plant community composition and distribution, hydrology, and wildlife value has been very limited in this region. Research has focused on Bass Harbor Marsh because of its proximity to the Worcester Landfill, potential impacts of "overboard discharge," and to the value of the Bass Harbor Marsh estuary.

Riverine System

The Riverine System includes all wetland and deepwater habitats contained within a channel and having a salinity of less than 0.5 parts per thousand ocean-derived salts. Vegetated riverine wetlands are dominated by nonpersistent plants (Cowardin et al. 1979) (Figure 19). Because watersheds in the Acadia region are typically small, they develop short drainage systems which generally empty into the sea within a few miles of their origin (NPS 1991). As a result, this area has many small streams and brooks with minimal floodplain habitat. Because of this, vegetated riverine wetlands are not extensive. However, patches of nonpersistent vegetation can be found along such major streams as Northeast Creek and Adams Brook.

Tidal fresh emergent wetlands

The lower reaches of streams draining into the ocean are influenced by tidal fluctuations and are classified as tidal fresh wetlands. In the Acadia region, the vegetation in this zone is dominated by persistent species (see section on Palustrine Emergent Wetlands), but patches of nonpersistents, including soft-stem bulrush (*Scirpus validus*), pickerelweed (*Pontedaria cordata*), arrowhead (*Sagittaria latifolia*), bladderworts (*Utricularia* spp.), and smartweeds (*Polygonum* spp.) occur. Stream setting may be responsible for the lack of well-developed zones of nonpersistent vegetation, including floating-leaved aquatics. Many of the streams in the study area drain peatlands and have low-energy shorelines supporting persistent emergent communities (*Carex* spp., *Typha* spp., and persistent grasses) or ericaceous scrub-shrub communities. The waters are generally high in organic acids and have a low pH (<6) discouraging development of aquatic beds dominated by more minerotrophic species. Rather, submergent aquatics adapted to low nutrient conditions, particularly *Utricularia* spp., may be more common.

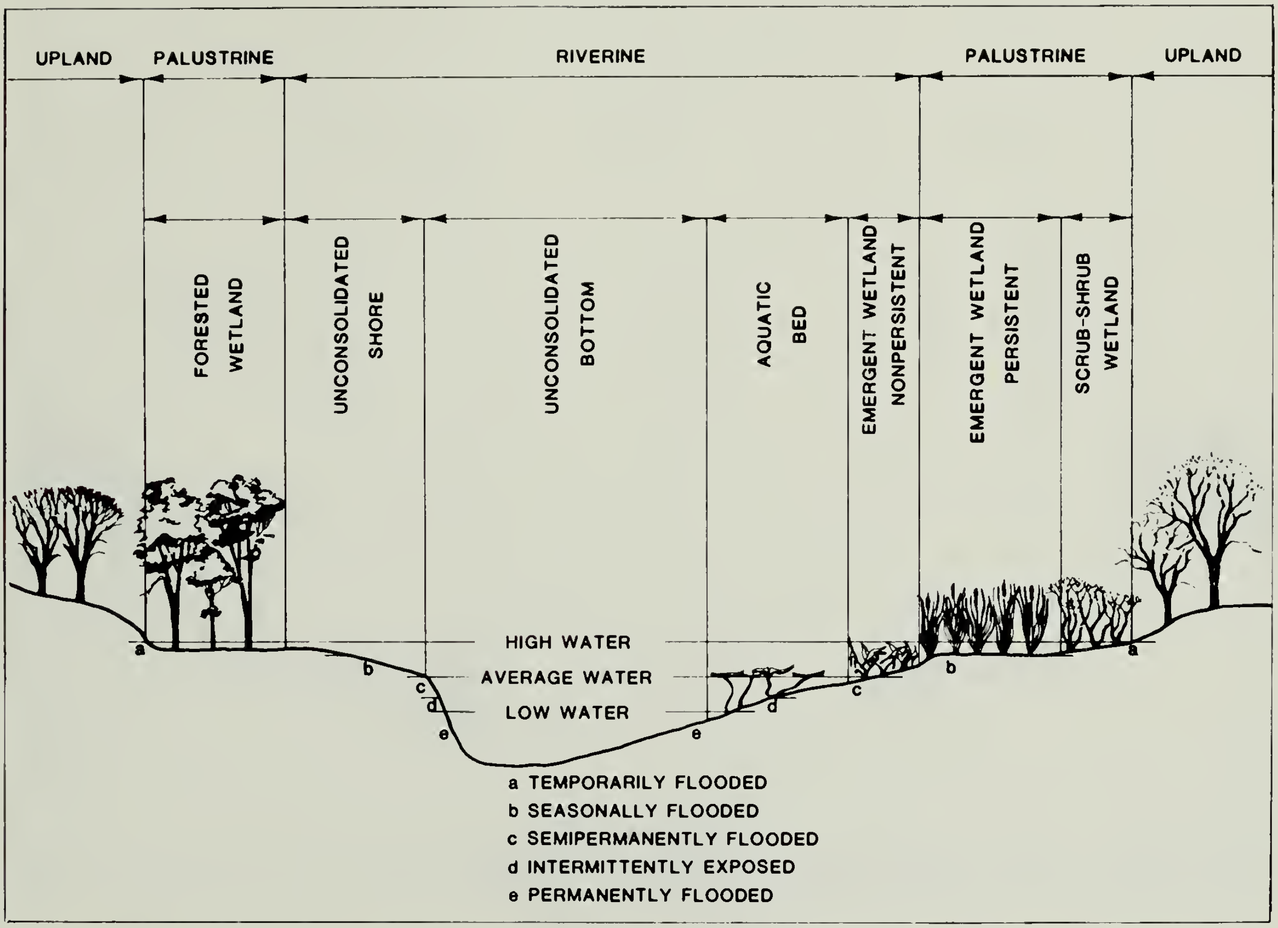


Figure 19. Distinguishing features and examples of habitats in the Riverine System (Cowardin et al. 1979).

Lower perennial emergent wetlands and aquatic beds

Riverine vegetation is not well developed along the major streams draining large wetland complexes such as Big Heath, Fresh Meadow, and Pretty Marsh. Mixed aquatic beds with *Utricularia* spp. (*U. intermedia, U. purpurea*) and such nonpersistent emergents as *Scirpus validus* and soft rush (*Juncus effusus*) are patchily distributed.

A population of horned pondweed (*Zannichellia palustris* L. var. *major*), a plant listed as a species of special concern in the state, occurs along Lurvey Brook.

Lacustrine System

Wetlands included in the Lacustrine System are situated in a topographic depression or dammed river channel where the total area of the open water exceeds 8 hectares (20 acres). Lacustrine vegetated wetlands are dominated by nonpersistent plants (Cowardin et al. 1979) (Figure 20). MDI is characterized by lakes running in a north-south orientation in steep-sided, forested basins. Echo Lake, Eagle Lake, Jordan Pond, and Long Pond are examples. Size class is diverse, with lakes ranging in size from 12 hectares (30 acres) (Bubble Pond) to almost 360 hectares (900 acres) (Long Pond) (Table 13).[4] They range from shallow, eutrophic habitats which support warm water fisheries (e.g., Aunt Betty Pond) to deeper, oligotrophic lakes (e.g., Eagle Lake) which support cold water fisheries.

Lacustrine marsh development varies with hydrogeologic setting. In smaller lakes in shallow basins, marsh development may be extensive. This is the case with Aunt Betty Pond, Round Pond, and Lower Hadlock Pond. In steeper sided lake basins, marsh development is restricted to

[4] The Maine State Planning Office has classified lakes in Maine as bodies of water over 4 hectares (10 acres) in size while the Cowardin et al. (1979) system uses an area of 8 hectares or more as the size criterion. This report follows the Cowardin system.

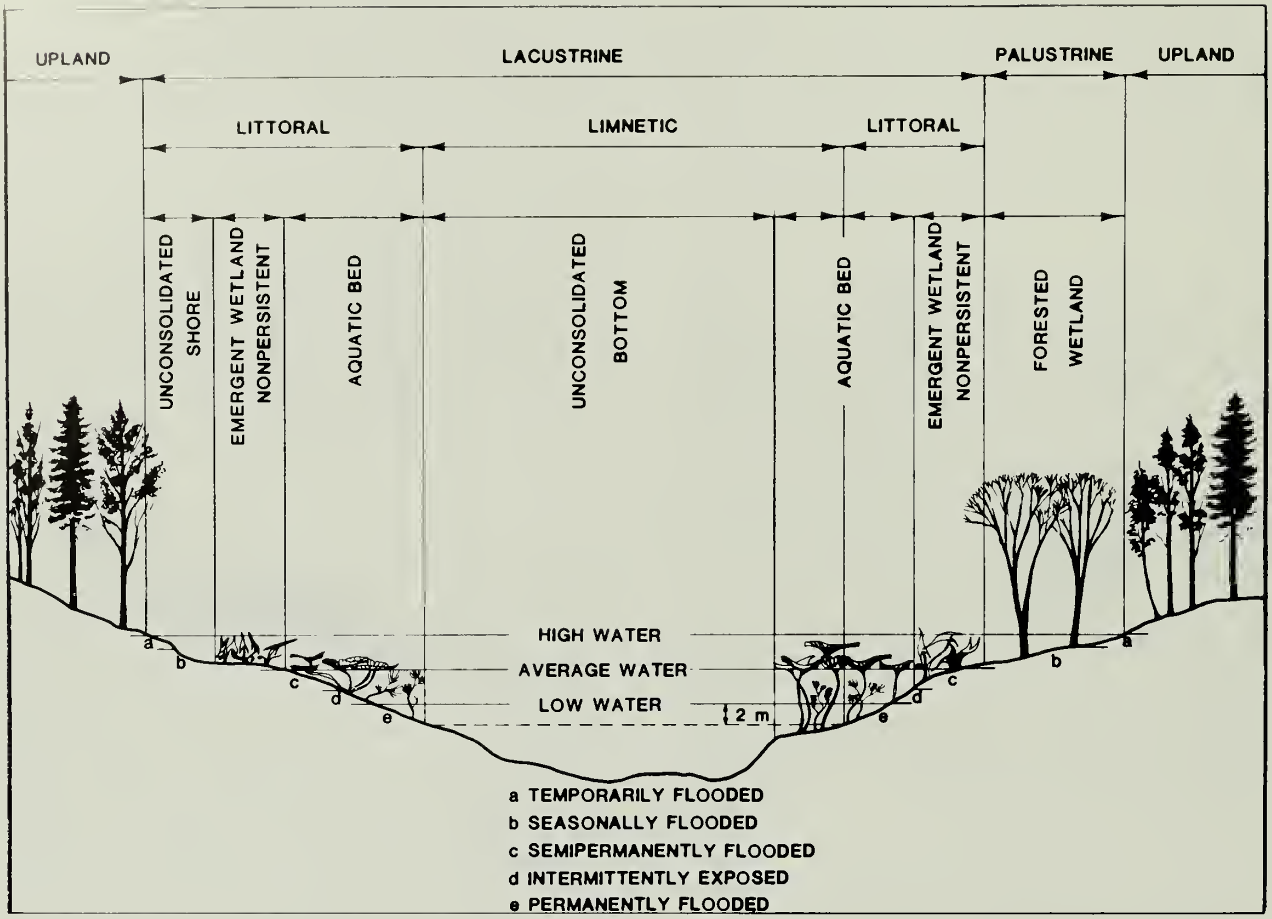


Figure 20. Distinguishing features and examples of habitats in the Lacustrine System (Cowardin et al. 1979).

sheltered coves along irregular sections of coastline and shallow sections, often at the north and south ends of the lakes (at stream inlets and outlets). Such lakes, distinguished by steep cliffs, rocky shorelines, pocket sand beaches, and bedrock outcrops, are common in the mountainous eastern region of MDI. Eagle Lake, Bubble Pond, and Jordan Pond are good examples.

Five lakes in the Acadia region—Aunt Betty Pond, Bubble Pond, Eagle Lake, Echo Lake, and Jordan Pond—have been recognized by the Maine State Planning Office as outstanding lakes (Parkin et al. 1989) (Appendix 3). Outstanding and significant features include scenic, botanic, cultural, wildlife, and geologic features. An additional 15 lakes have at least one outstanding or significant feature (Table 13).

Lacustrine aquatic beds and marshes

The most common floating aquatic plants in the region's lakes are white water lily (*Nymphaea odorata*), spatterdock (*Nuphar variegatum*), and pondweeds (*Potamageton* spp., including ribbonleaf pondweed [*P. epihydrus*]). Floating heart (*Nymphoides cordata*) and the floating or submergent form of burreeds (*Sparganium* spp.) have also been noted. Emergent communities, developing along shallow shores and in coves, are dominated by bayonet rush (*Juncus militaris*). More patchily distributed stands of *Pontedaria cordata*, common arrowhead (*Sagittaria latifolia*), common pipewort (*Eriocaulon septangulare*), bittercress (*Cardamine pensylvanica*), and hard-stemmed bulrush (*Scirpus acutus* Muhl.) are present in some of the lakes. Bishop and Clark (1923) note over 20 species of aquatic plants in Long Pond on Isle au Haut. Aunt Betty Pond and Round Pond, owing to their smaller size, shallow basins, and eutrophic status, are dominated by aquatic vegetation, including water lilies, purple bladderwort (*Utricularia purpurea*), and flat-leaf bladderwort (*U. intermedia*). Lacustrine marsh communities may grade into palustrine marshes and shrub swamps, particularly along less steep-

Table 13. Significant features of lakes and ponds in Acadia National Park and vicinity.

Lake/Pond	Acres	Botanical	Shoreline	Fisheries
Aunt Betty Pond	34	O[1]		S
Bubble Pond	32	S	S	S
Eagle Lake	436	S		S
Echo Lake	237	S	O	S
Jordan Pond	187	S	O	S
Long Pond	897			S
Lower Hadlock Pond	39			S
Upper Hadlock Pond	35			S
Witch Hole Pond	28			S
Long Pond (Isle au Haut)	73			
Hodgdon Pond	35			
Long Pond (little)	38			S
Round Pond	38			S
Somes Pond	104			S
Goose Pond (Swans Island)	38			
Beaver Dam Pond	7.5			
Breakneck Pond (Lower)	8			
Breakneck Pond (Upper)	9			
Halfmoon Pond	3			
Lake Wood	16			
Little Round Pond	16			
The Bowl	10.4			
The Tarn	8			

[1] (Adapted from Parkin et al. 1989) "O" designates an outstanding resource, while "S" signifies a significant resource. A blank indicates that the water body did not meet the study's minimum standards or that there was insufficient information.

sided shores and at the inlet and outlet of streams associated with the lake.

Two rare plants, water awlwort (*Subularia aquatica* L.) and small purple bladderwort (*Utricularia resupinata*), occur in lacustrine habitats in the region. The former occurs in Eagle Lake, Bubble Pond, and Long Pond on Isle au Haut. The latter has historically been found in Aunt Betty's Pond although a current site has not been found. Arethusa (*Arethusa bulbosa*) occurs in palustrine marshes associated with Echo Lake. Descriptions of aquatic plant communities and other botanical features (including rare species) for a number of lakes and ponds in the Acadia region can be found in Parkin et al. (1989).

Water chemistry studies on lakes and streams in the Acadia region were conducted by the University of Maine and cooperative monitoring projects are ongoing through the Maine Department of Environmental Protection. Many of the studies focus on the impacts of acid rain and heavy metals on freshwater resources. (See Heath et al. [1989] and Kahl et al. [1987] for more information). A compilation of hydrologic studies and study sites (lakes and streams) is listed in Greene et al. (1992).

Palustrine System

The Palustrine System comprises wetlands traditionally called swamps, bogs, fens, and marshes. Palustrine wetlands are nontidal, freshwater systems including open water bodies less than 8 hectares (Cowardin et al. 1979) (Figure 21). This is the most common wetland system in the Acadia region. The largest diversity of plant communities and overall species diversity occurs in palustrine wetlands owing to the wide range of hydrogeologic settings within which these wetlands form (see Chapter 4).

Palustrine aquatic beds

Ponds, or bodies of water less than 8 hectares in area, are an integral part of the glaciated landscape of the Acadia region. The Tarn, lower and upper Breakneck Ponds, Halfmoon Pond, and Lake Wood—to name but a few of the region's palustrine aquatic habitats—support both submergent and floating aquatic communities.

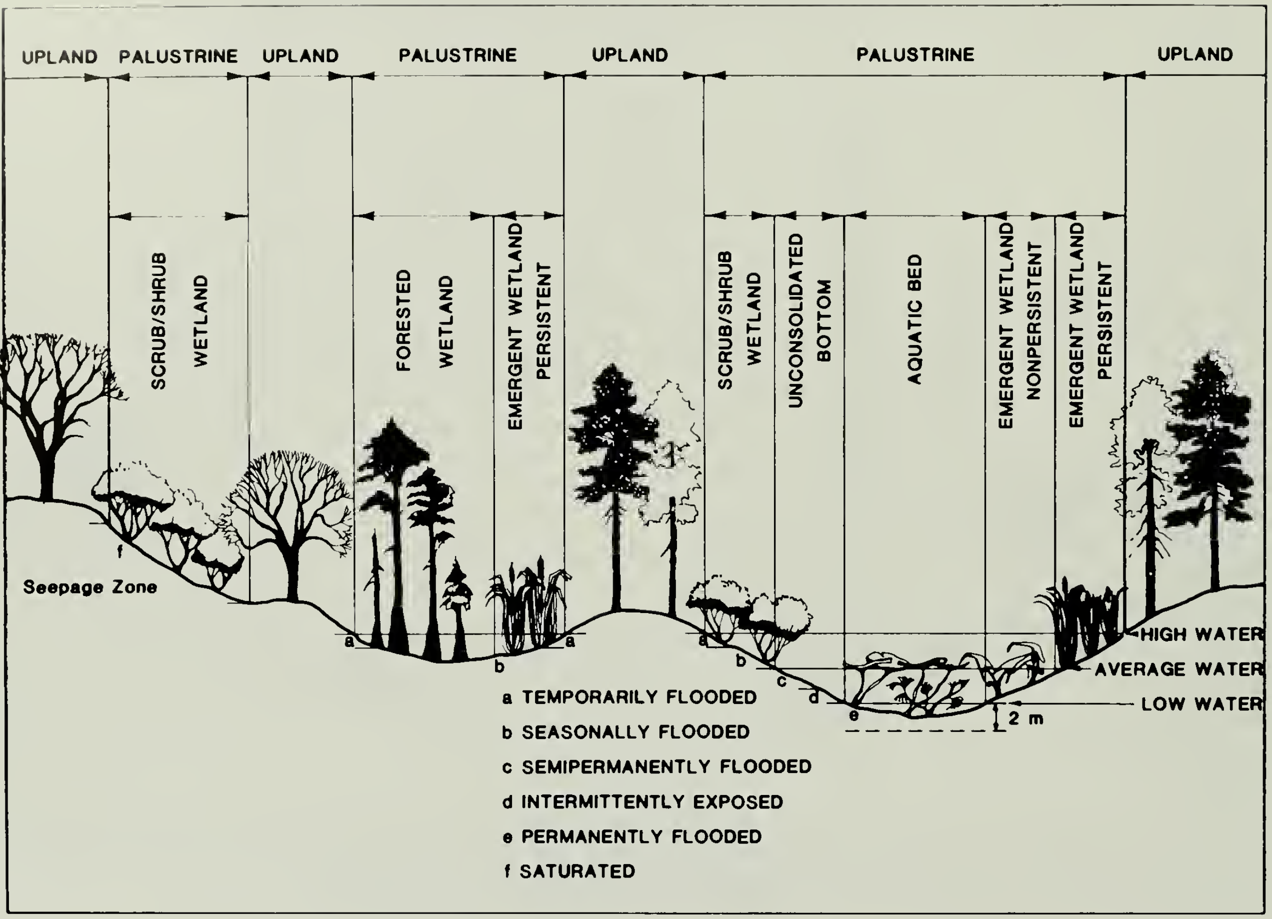


Figure 21. Distinguishing features and examples of habitats in the Palustrine System.

However, they vary in nutrient status from the eutrophic Tarn to the oligotrophic Lake Wood. Therefore, some support extensive aquatic beds (the Tarn, coves of the Breakneck Ponds), while others are characterized by extensive shrub fens and other acid wetlands along the perimeter with minimal aquatic bed development (e.g., The Bowl). These wetlands are either permanently or semi-permanently flooded. Green algae, floating plants such as duckweed (*Lemna minor*), and rooted vascular plants including *Potomageton epihydrus*, *Utricularia purpurea, U. intermedia*, *Nymphaea odorata,* and *Nuphar variegatun* are common aquatic bed species. Often these plants are associated with emergent species including *Eriocaulon septangulare, Pontedaria cordata*, and *Sagittaria latifolia.* The spectacular summer display of blooming water lilies and bladderworts prompted Kuchler (1956) to refer to Aunt Betty Pond and the Tarn as "flowering lakes." [5]

Palustrine emergent wetlands

Palustrine emergent wetlands include tidal fresh marshes, freshwater marshes, wet meadows (including beaver meadows), and fens and bogs dominated by persistent herbaceous vegetation. The previously discussed lacustrine and riverine emergent wetlands are dominated by nonpersistent herbaceous vegetation. Palustrine emergent wetlands develop in a variety of hydrogeologic settings and may have tidal fresh, semi-permanently flooded, seasonally flooded, saturated, and temporarily flooded water regimes. Common plants associated with palustrine emergent wetlands are shown in Table 12.

[5] Mt. Desert Nurseries planted 1000 water lilies and arrowheads in the Tarn in 1939 (Zabinski-Gormley and Olday 1977).

Emergent wetlands associated with major streams

Marshes are commonly associated with streams and may develop along the edges of the stream (permanently or semi-permanently flooded) or within the stream floodplain (seasonally flooded and/or seasonally saturated). Oftentimes the stream edge communities are mixed with aquatic beds (riverine marshes) or scrub-shrub communities.

Tidal fresh emergent marshes. Tidal fresh marsh communities in the Acadia region form a transition zone between salt marshes and nontidal fresh marshes. The hydrologic regime in these settings varies both spatially and temporally making the boundary between estuarine and palustrine marshes both dynamic and indistinct. Furthermore, the hydrologic inputs to these streamside communities may not be totally dependent on stream activity; groundwater input and surface flow from adjacent habitats may be a significant part of the hydrologic budget explaining the complex nutrient and water regimes in any one wetland. As a result, vegetation is patchily distributed as dictated by local factors including substrate conditions, hydrologic inputs, and variability in salinity and pH. Even so, broad patterns in vegetation composition exist among these stream marsh systems.

In the transition zone between salt marsh and fresh marsh communities, the wetlands have formed in postglacial marine sediments or glacial drift. Organic layers here are often shallower than organic accumulations in typical salt marsh soils (i.e., typically much less than 40 centimeters of organic matter) such as are found in Bass Harbor Marsh and Mitchell Cove. Often these marshes are adjacent to or mixed with shrub fens and forested wetland communities. In the zone closest to the stream, a mixture of *Spartina pectinata, S. patens, Scirpus maritimus, S. validus, Juncus gerardii,* spreading bent grass (*Agrostis stolonifera*), *Calamagrostis canadensis,* and *Festuca rubra* is commonly supported. Swamp candles (*Lysimachia terrestris*), *Aster umbellatus, Potentilla anserina*, and *Triglochin maritimum* are also present in this zone. In some cases, this zone is dominated by *Carex paleacea*, *Spartina pectinata,* and *Juncus balticus.* Other common plants found in the marsh floodplain are *Juncus effusus*, *Scirpus validus*, wool grass (*S. cyperinus*), common threesquare (*S. maritimus*), *S. pungens*, *Juncus gerardii, Calamagrostis canadensis, Agrostis gigantea* Roth., *Agropyron repens*, bladder sedge (*Carex intumescens*), beaked sedge (*C. rostrata*), *C. lupulina, Spartina pectinata, Lysimachia terrestris, Myrica gale,* and *Spirea latifolia.* Often the marshes grade into peatlands as evidenced by the presence of *Sphagnum* spp., *Chamaedaphne calyculata*, and *Vaccinium macrocarpon* along the upper borders. Also noted in this community, though less common, are slender sedge (*Carex tenera*), seaside crowfoot (*Ranunculus cymbalaria*), and broad-leaved cattail (*Typha latifolia*).

Excellent examples of the transitional marsh habitat can be seen along Northeast Creek through Fresh Meadow (east of Route 3) and in the upper reaches of streams draining into Bass Harbor east and west of Route 102. A dramatic example of estuarine to tidal fresh habitats can be seen at Sand Beach where the sea breaches the beach on the eastern shore. The estuarine habitat gives way to a series of well-developed freshwater beaver meadows to the north.

Fresh marshes (nontidal). The upper end of the tidal fresh zone is marked by subtle changes in vegetation as influences from saline intrusion and proximity to salt marsh seed sources are reduced. The emergent wetlands at the upper reaches of the streams are frequently adjacent to shrub and forested wetlands. Examples of this can be seen at the upper reaches of the streams draining both Fresh Meadow and Bass Harbor Marsh. The gentle micro-topography of the salt marsh/transitional marsh floodplains is replaced by more distinct mounds and hummocks created by cespitose graminoids such as tussock sedge (*Carex stricta*). Along the channels, *Scirpus validus, Calamagrostis canadensis, Spartina pectinata, Typha angustifolia,* and *T. latifolia* may dominate. The vegetation immediately adjacent to the river channel tends to occur in monotypic patches of these species, often with one side of the channel dominated by one species while the other side is characterized by another.

The community diversifies with distance from the stream edge. Common graminoids in this zone include *Carex stricta*, *C. rostrata, Scirpus cyperinus*, Canada rush (*Juncus canadensis*), *Calamogrostis canadensis, Carex lacustris* Willd., *C. lasiocarpa,* and *Eleocharis palustris.* Woody species such as *Spirea tomentosa, S. latifolia, Myrica gale,* and *Vaccinium macrocarpon* are often scattered throughout the emergent vegetation with increasing density toward the landward border of the emergent marsh. Forbs not recorded in the tidal fresh marshes but typical of these nontidal fresh marshes include blue flag (*Iris* *versicolor*), *Hypericum virginicum*, *Rumex crispus*, Pennsylvania buttercup (*Ranunculus pensylvanicus*), arrowthumb smartweed (*Polygonum saggitatum*), marsh skullcap (*Scutellaria epilobiifolia*), common pondweed (*Potamogeton natans*), water parsnip (*Sium suave*), and marsh bedstraw (*Galium palustre*). Nontidal fresh marsh and adjacent shrub communities are common along Marshall, Lurvey, and Heath brooks which drain into Bass Harbor Marsh. A canoe trip through Bass Harbor Marsh and Fresh Meadow, beginning at the ocean outlet, illustrates the vegetation changes from salt marsh, tidal fresh marsh, to nontidal fresh marsh.

Palustrine freshwater marshes also are common along the shores of lakes and ponds. Often a community of persistent emergent plants develops to the landward zone of lacustrine nonpersistent emergent marshes. Common persistent marsh plants associated with lake wetland classes and palustrine open water (ponds) include *Carex lacustris, C. intumescens, C. echinata* Murray, *C. cryptolepsis* Mackenzie, *C. lasiocarpa* Ehrh., *Scirpus acutus* Muhl., three-way sedge (*Dulichium arundinaceum*), *Lysimachia terrestris*, great burreed (*Sparganium eurycarpum*), *Typha latifolia,* and umbrella sedges (*Cyperus* spp.). Examples of emergent marshes associated with palustrine open water (ponds) can be seen at Little Round Pond and Breakneck Ponds and on the eastern shore of MDI. Pond/marsh systems have formed in the low-lying land east of Champlain Mountain and west of Cranberry Hill and Schooner Head. These marshes can be seen from Schooner Head Road or the Park Loop Road which parallels it. Long Pond, Aunt Betty Pond, and the southern ends of Seal Cove Pond and Upper Hadlock Pond also provide examples of adjacent lacustrine/palustrine emergent marsh communities.

Emergent peatlands[6]

Bog lawns. MDI, Swans Island, the Cranberry Isles, and Isle au Haut are rich in peatlands. Extensive peat deposits have developed in depressions, along streams in river valleys, and on the extensive glaciomarine deposits associated with this region. These landscape units support herbaceous communities (bog lawns and emergent fens), scrub-shrub communities (scrub-shrub bogs and fens), and forested communities (black spruce bogs).

Bog lawns are emergent peatlands found on the wetter plateaus of the coastal raised bogs (A. Damman, Connecticut College, pers. comm.). This wetland community is represented in isolated patches in Big Heath at the southern tip of MDI (particularly around the ponds on the southern edge of the peatland), Great Meadow on Isle au Haut, and in the Great Cranberry Isle Heath. These areas may include such graminoid species as tufted bulrush (*Scirpus cespitosus*), coast sedge (*Carex exilis*), and tawny cotton grass (*Eriophorum virginicum*), narrow-leaved cotton grass (*E. angustifolium*), and/or hare's tail (*E. spissum*). White beakrush (*Rhyncospora alba*), smooth sawgrass (*Cladium mariscoides*), and *Juncus canadensis* are common in bog lawns on the smaller islands, including the Cranberry Islands. Associated woody species, often under 10 centimeters tall, include dwarf huckleberry (*Gaylussacia dumosa*), sheep laurel (*Kalmia angustifolia*), bog laurel (*K. polifolia*), *Myrica gale, Chamaedaphne calyculata, Aronia melanocarpa,* bog rosemary (*Andromeda glaucophylla*), small cranberry (*Vaccinium oxycoccus*), and black crowberry (*Empetrum nigrum*). The secondary ponds (ponds formed after development of the bog) associated with the bog lawn at Big Heath are unusual in supporting *Nymphaea odorata* and *Nuphar variegatum.* Yellow-eyed grass (*Xyris caroliniana*) is also found around the ponds. Orchids, including *Arethusa bulbosa* and grass pink (*Calopogon pulchellus*), are noteworthy denizens of this community. Such insectivorous plants as spoon-leaf (*Drosera intermedia*) and round-leaved sundew (*D. rotundifolia*), pitcher plant (*Sarracenia purpurea*), and horned (*Utricularia cornuta*) and common bladderwort (*U. vulgaris*) also grow here.

Moore and Taylor (1941) described a small bog near Bass Harbor dominated by sedges with a subdominant dwarf shrub community. Common species identified by them include Eastern sedge (*Carex atlantica*), few-seeded sedge (*C. oligosperma*), *Rhyncospora alba,* and *Eriophorum angustifolium.* Reference to the bog lawns at Big Heath and Great Meadow on Isle au Haut can be found in Worley (1980) and Gawler (1982), respec-

[6] For the purposes of this report, peatland refers to wetlands with organic soils as defined by the SCS, including peat, muck, and mucky peat designations used by SCS as well as very poorly drained Histosols. The term "bog" is restricted to nutrient-poor, acidic, ombrotrophic peatlands with a moss layer dominated by sphagnum mosses. Bogs may support wooded and/or herbaceous communities. Black spruce and tamarack are typical wooded bog species. Fens occur on minerotrophic sites and are richer in nutrients and less acidic than bogs. Fens support herbaceous and/or shrub communities. For this report, bog shrub communities will be restricted to the raised peatlands unique to this region although technically the distinction between poor shrub fen and shrub bog is indistinct.

tively. As emergent fens are typically associated with ombrotrophic bogs, the fen/bog classification may become less distinct as species may overlap, as described below.

Emergent fens. Fens, or minerotrophic peatlands, dominated by graminoids are commonly found on the smaller islands associated with MDI (Cranberry Isles, Swans Island, Isle au Haut). By contrast, many of the fens on MDI are dominated by shrubs, with emergent fens generally restricted to associations with larger peatland complexes (bogs) or areas with disturbed water regimes (e.g., resulting from road work, development, or beaver activities). Occasionally flooded, these wetlands display cradle-and-mound microtopography and are typically dominated by *Carex* spp. (poor sedge [*C. paupercula*], *C. oligosperma, C. lasiocarpa, C. exilis,* and others), *Eriophorum virginicum, Rhyncospora alba, Cladium mariscoides,* and *Scirpus cyperinus.*

An emergent fen on the southern half of Sunken Heath (located on northern MDI) is described by Gawler (1982). Common graminoids in Sunken Heath, as listed by Welch (1985), include *Scirpus cespitosus, Eriophorum angustifolium, E. spissum*, delicate cotton grass (*E. tenellum*), *Carex exilis*, long-seeded sedge (*C. folliculata*), *C. lasiocarpa*, and *Rhyncospora alba*. A fen associated with Great Cranberry Isle Heath, located on the western arm of the heath, is described by Gawler (1982) as a typical fen dominated by sedges, including mud sedge (*Carex limosa*).

On the smaller islands, emergent fens are common along roads where the water regime has been altered leaving one side wetter (emergent fen) and the other drier (shrub fen). In these areas, *Rhyncospora alba* and *Scirpus cyperinus* are dominant with *Eriophorum angustifolium* often occurring as a subordinate.

A roadside fen with both emergent and shrub communities is located to the west of the Park Road just north of Pond Island on Schoodic Peninsula. An impressive view of an emergent/shrub fen can be seen on the eastern loop of the Witch Hole Pond carriage trail at the northeastern end of the Pond. Another mixed wetland complex including emergent/shrub fen communities and forested wetlands is Great Meadow, accessed from the Sieur de Monts Spring parking area. This large wetland mosaic occupies the valley between Dorr and Kebo Mountains to the west and the north-south ridge of hills to the east.

Palustrine scrub-shrub wetlands

Second only to the forested wetland class in abundance, the scrub-shrub community is dominated by shrubs (including prostrate and low, compact shrubs) or tree saplings less than 6 meters tall (Cowardin et al. 1979). These wetlands are found in a variety of hydrogeologic settings—at the borders of stream courses and barrier beach ponds (semi-permanently flooded), in peatlands perched on glaciomarine sediments and/or bedrock (saturated water regimes), in seasonally flooded regimes in hydric mineral or muck soils bordering salt marshes, in wet swales along roadsides, and around lakes, brooks, and ponds. Plant diversity and community structure is highly variable depending on proximity to other wetland classes, hydrology, disturbance history, soil type, and nutrient status. Shrub swamps in the Acadia region are usually associated with large wetland complexes including forested and emergent wetlands. Many of the region's peatlands are dominated by scrub-shrub communities.

Scrub-shrub bogs

The scrub-shrub communities on the coastal raised bogs are ombrotrophic and are typically saturated to the surface from November through July. The water table usually drops by summer's end. Waskish soils are typical of these areas. Shrub bogs are dominated by low shrubs (less than 45 centimeters) and may have a distinct pattern of hummocks (cradle-and-mound microrelief), low mudflats, and bare waterways and/or game trails transecting them. Secondary ponds are a rare feature of these raised bogs, but are present in Big Heath. The drainageways, mud bottoms, game paths, and disturbed areas in general tend to support *Utricularia cornuta*, *Drosera intermedia* and/or *D. rotundifolia,* and *Sphagnum cuspidatum.* Shrubs are interspersed with islands of black spruce (*Picea mariana*), or larch (*Larix laricina*), with the broad-leaved deciduous shrubs being less important. Hummocks also may support low-compact shrubs such as *Chamaedaphne calyculata, Gaylussacia dumosa,* and Labrador tea (*Ledum groenlandicum*), or prostrate shrubs such as cloudberry (*Rubus chamaemorus*). *Cladonia-Empetrum nigrum* hummocks occur in some of the bogs and are an indicator of the maritime influence. Mixed shrub communities may include the above species and dwarfed forms of low sweet blueberry (*Vaccinium angustifolium*), labrador tea (*Ledum groenlandicum*), black huckleberry (*Gaylussacia *baccata*), and *G. dumosa*, *Kalmia angustifolia*, and rhodora (*Rhododendron canadense*) with more patchily distributed species including *Juniperus communis*, *Andromeda glaucophylla, Kalmia polifolia,* wild raisin (*Viburnum cassinoides*), *Myrica gale, Larix laricina,* and *Picea mariana*. Woody prostrate plants, also locally distributed, include *Vaccinium macrocarpon, Vaccinium oxycoccus, Empetrum nigrum,* and *Rubus chamaemorus.*

Many species of graminoids and forbs are associated with these shrub communities and may dominate in localized areas such as game trails, and on the wetter plateaus of the coastal plateau bogs. *Eriophorum virginicum*, *Scirpus cespitosus*, and *Carex exilis* are important on MDI, while *Rhyncospora alba*, *Cladium mariscoides*, and *Juncus canadensis* are also important on some of the smaller islands. Bog aster (*Aster nemoralis*), skunk cabbage (*Symplocarpus foetidus*), bog goldenrod (*Solidago uliginosa*), and *Sarracenia purpurea* are among the more common herbs encountered, while the orchids, *Calopogon pulchellus,* rose pogonia (*Pogonia ophioglossoides*), *Arethusa bulbosa,* and *Arethusa bulbosa* forma *albiflora* R. & R., although present, are less apparent (they have a brief flowering period and their leaves are inconspicuous). Herbs are more abundant in dwarf scrub-shrub communities. Common ground cover includes various species of mosses, lichen (particularly in fire-impacted areas), and liverworts. Major species include *Sphagnum fuscum, S. pulchrum, S. rubellum, S. flavicomans, Cladonia alpensis, C. arbuscular, C. gracilis*, and *Polystichum strictum.*

Reference to shrub bogs, including Sunken Heath, Keith's Heath, and Morrison's Heath (all on northern MDI), can be found in Gawler (1982), Welch (1985), and Potzger and Friesner (1948). Descriptions of ombrotrophic shrub bogs and related literature are discussed in "Unique peatland features" below.

Scrub-shrub fens

Fens are peatlands that are not limited to rainwater or minimal groundwater/surface water inputs as a source of nutrients, but rather receive significant hydrologic inputs from groundwater, stream water, and/or surface runoff from the surrounding landscape (making them richer in nutrients than bogs). In the Acadia region, soils in fens are most commonly well-decomposed organic soils (Bucksport and Wonsqueak). Shrub fens may flood early in, and generally are saturated throughout, the growing season. Depending on the source of water and the condition of the watershed feeding the fen, the nutrient status may vary considerably among shrub fens.

The richest fens, often adjacent to streams and other wetland classes, are dominated by a diversity of tall shrubs such as *Rhododendron canadense, Aronia melanocarpa,* mountain holly (*Nemopanthus mucronata*), highbush blueberry (*Vaccinium corymbosum*), *Viburnum cassinoides, Spirea tomentosa* and *Spirea latifolia*. Less common tall shrubs include *Larix laricina*, red maple (*Acer rubrum*), and *Picea mariana*. Structure is well developed in rich fens. Below the tall shrub stratum, a low shrub layer dominated by *Ledum groenlandicum, Kalmia angustifolia, Myrica gale,* and *Chamaedaphne calyculata* is common. Other shrubs may be present, including *Myrica pensylvanica, Picea mariana, Juniperus communis,* and *Vaccinium angustifolium.* The herb layer is similar in composition to those reported in bogs with the addition of false Solomon's seal (*Smilacina trifolia*), *Carex paupercula, Iris versicolor,* and three-seed sedge (*Carex trisperma*). Scattered trees—*Acer rubrum, Picea mariana,* northern white cedar (*Thuja occidentalis*), and *Larix laricina*—are a common feature of the larger fens. Sphagnum cover may blanket the ground and cradle-and-mound microtopography is often dramatic.

Poorer (less nutrient-rich) fens differ from rich fens in both structure and species diversity. Often the tall shrub layer is absent or unimportant and shrub species diversity is lower. Herb communities are similar, but *Sphagnum* spp. may be patchy with bare mud holes being common. Shrub fens are associated with Big Heath, Bass Harbor Marsh (particularly along the Adam's Brook east of Route 102), and Fresh Meadow.

Shrub fens border Witch Hole Pond. A good view of this community can be seen along the carriage trail that follows the western shore of the pond. A fen community supporting dwarfed white pine also can be seen here.

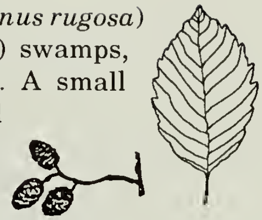
Unique peatland features

To maintain consistency, the above descriptions for emergent wetlands and scrub-shrub wetlands follow the Cowardin et al. (1979) classification system employed by the National Wetlands Inventory and do not follow the classification system specific to peatlands in this region of Maine developed by Worley (1981) or Damman and French (1987). However, it should be noted that the Acadia region has examples of the rare raised peatland type, the Coastal Plateau Bog, which is characterized by unique natural features of both local and continental significance. These peatlands are generally complexes of bog and fen habitats supporting both herbaceous and woody plant communities. Limited in distribution to a narrow band of islands and headlands along the eastern coast of Maine to New Brunswick (Figure 22), this raised peatland type describes a unique climatic and biogeographical zone (Damman 1977; Worley 1980). Figure 23 illustrates the typical topographic and vegetation patterns of these wetlands. Some of the plant species described above, including *Scirpus cespitosus, Sphagnum fuscum, Symplocarpus foetidus, Empetrum nigrum, and Rubus chamaemorus*, are diagnostic of this peatland type. Descriptions of two coastal plateau bogs (described above as shrub/emergent bogs), Big Heath and Great Cranberry Isle Heath, both occurring in the study area, have been prepared by Worley (1981) and Gawler (1982). Big Heath (Seawall Bog) has been placed on the Register of Critical Areas, while Great Cranberry Isle Heath has been recognized as an outstanding natural feature by the Maine Critical Areas Program. For a complete discussion of the national significance of this wetland type and the unique climatic, vegetation, morphological, and ecological features of coastal plateau bogs in general, see Damman (1977) and Worley (1980). Table 12 illustrates some of the common peatland plants.

Peatlands in the Acadia region host a number of rare plants: inkberry (*Ilex glabra*), cloudberry (*Rubus chamaemorus*), *Arethusa bulbosa*, and screw stem (*Bartonia paniculata*) to name a few.

Other shrub communities

Semi-permanently flooded shrub communities develop as narrow strips along streams and are dominated by *Chamaedaphne calyculata*, *Myrica gale*, and *Spirea latifolia*. These communities are also adjacent to, or mixed in with, emergent wetlands bordering large streams. In some cases where organic soils predominate, these strips of vegetation could be described as shrub fens. Brooks or small streams associated with lakes and ponds often support a narrow zone of shrub swamp (mineral soils) with a mixture of *Ilex verticillata, Spirea latifolia, Rosa nitida* Willd., *Alnus* spp., and *Myrica gale* being common. Often these shrub zones form a dense thicket to the landward edge of lakes and ponds.



Pure speckled alder (*Alnus rugosa*) and green alder (*A. crispa*) swamps, however, are less common. A small alder wetland occurs behind the Seawall barrier beach and is associated with a larger wetland complex. A narrow band of alder may form around lake and pond edges as well (Lake Wood for example). Most of the alder shrub swamps found in this study were adjacent to salt marshes (as in Mitchell Cove salt marsh west of the Bernard Road and bordering salt marshes associated with Schoodic Peninsula), along roadsides, or occupying small isolated patches of swamp rather than forming extensive shrub wetlands. (Alder shrub wetlands should not be confused with alder stands that reclaim abandoned fields, such as those seen south of the Tarn and immediately along the coast.)

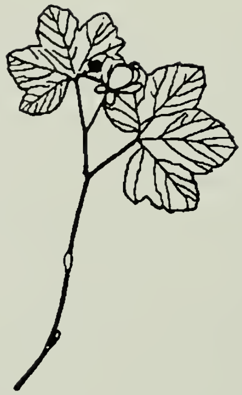
Community descriptions for shrub peatlands and unique peatlands in the Acadia region occur in the literature as described above. However, there is limited information on freshwater marsh and peatland hydrology on MDI. Research on atmospheric deposition by Kahl et al. (1985) and Norton and Kahl (1987) was conducted on cores from ombrotrophic peat deposits in ANP, and Tolonen et al. (1988) studied peat accumulation rates and pollen in Big Heath. Pollen profiles were also constructed for Keith and Morrison Heaths by Potzger and Friesner (1948). Minimal water chemistry data are provided by Welch (1985) for Sunken Heath. Fefer and Schettig (1980) and Worley (1980) have mapped bogs in ANP.

Palustrine forested wetlands

Forested wetlands are the most abundant wetland class in the study area and constitute the majority of the mapped wetlands. (It should be noted that the extent of forested wetland coverage is probably much greater than the actual mapped areas as these wetland ecosystems are difficult to identify from aerial photography.) They are located along streams, in isolated depressions, in conjunction with other wetland classes in low-lying areas, and particularly on the smaller islands, in association with hillside seeps (groundwater slope wetlands). Forested wetland communities may be dominated by evergreens, hardwoods, or a mixture of the two depending on disturbance factors, water regimes, stochastic events, and nutrient status. The fire of 1947

Scirpus cespitosus

Carex exilis



Baked-apple berry, *Rubus chamaemorus*

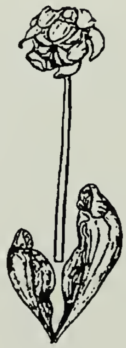
Small cranberry, *Vaccinium oxycoccos*

Intermediate-leaved sundew, *Drosera intermedia*

Narrow-leaved cotton-grass, *Eriophorum angustifolium*

Sheep laurel, *Kalmia angustifolium*

Sweet gale, *Myrica gale*



Pitcher plant, *Sarracenia purpurea*

Leather-leaf, *Chamaedaphne calyculata*

Some Peatland Plants of the Palustrine System (adapted from Worley 1980/1981)

(Figure 24) affected forest composition in general as hardwood species and the fire-resistant pitch pine were favored over softwoods. Fire history may account for the large number of hardwood swamps with evergreen understories and the lack of extensive larch and cedar swamps as regeneration of larch and cedar on burned sites is minimal (Kuchler 1956; Patterson and Backman 1988). Monotypic, even-aged forested wetlands dominated by birch and aspen may be a result of fire as well (Kuchler 1956). Kuchler (1956) also notes that some communities were able to return, with little change in species composition, including many black spruce bogs. As in the upland communities, wetland forests have seen an expansion of hardwoods while spruce, fir, and cedar have declined. Common wooded wetland species are listed in Table 12.

The predominant water regime for these nontidal wetlands ranges from seasonally flooded (usually in the mineral wetlands) to saturated or seasonally saturated regimes in organic soils.

Evergreen forested wetlands

Needle-leaved evergreen forested wetlands are characterized by one of three species: (1) northern white cedar (*Thuja occidentalis*); (2) red spruce (*Picea rubens*); and (3) black spruce (*Picea mariana*).

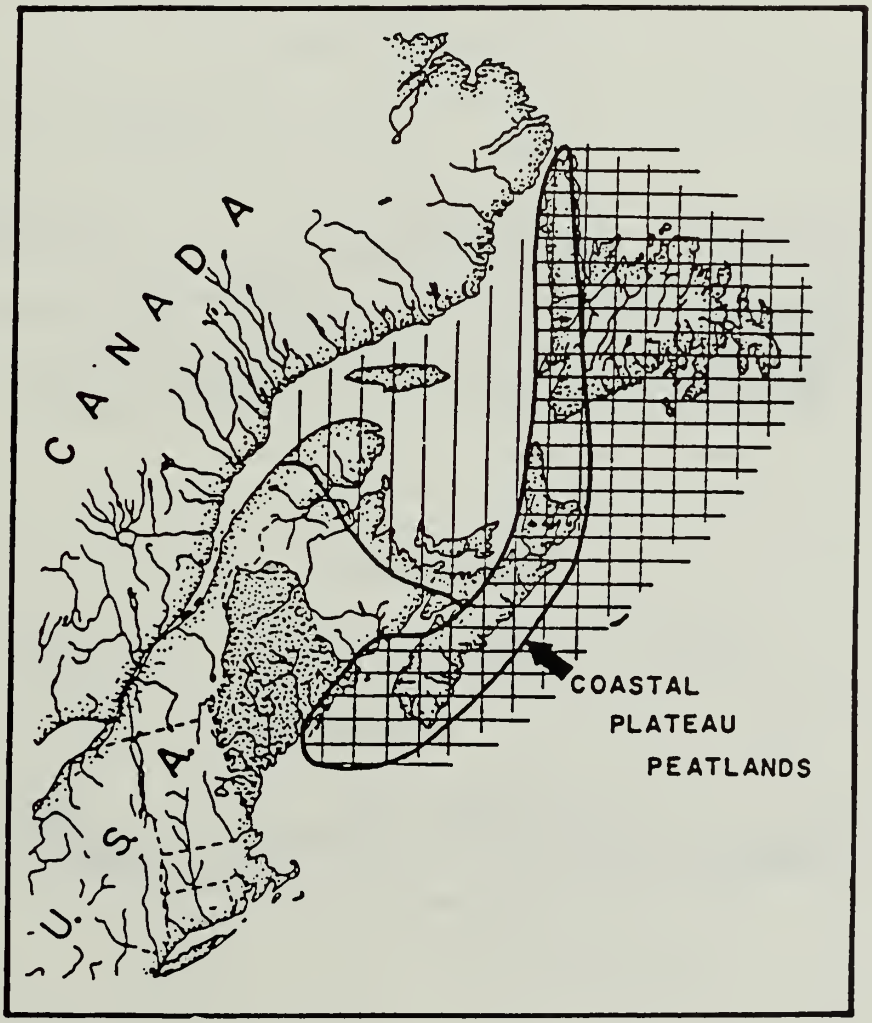


Figure 22. Eastern North American distribution of coastal plateau peatlands, Scirpus *lawn communities, and the phenomenon of minerotrophic species on ombrotrophic peats. The area with vertical lines contains* Scirpus cespitosus *lawns (of the* Scirpo-Sphagnetum) *on ombrotrophic peatland. The area with horizontal lines has ombrotrophic peatlands containing species restricted to minerotrophic sites in other parts of eastern North America. From Worley (1980).*

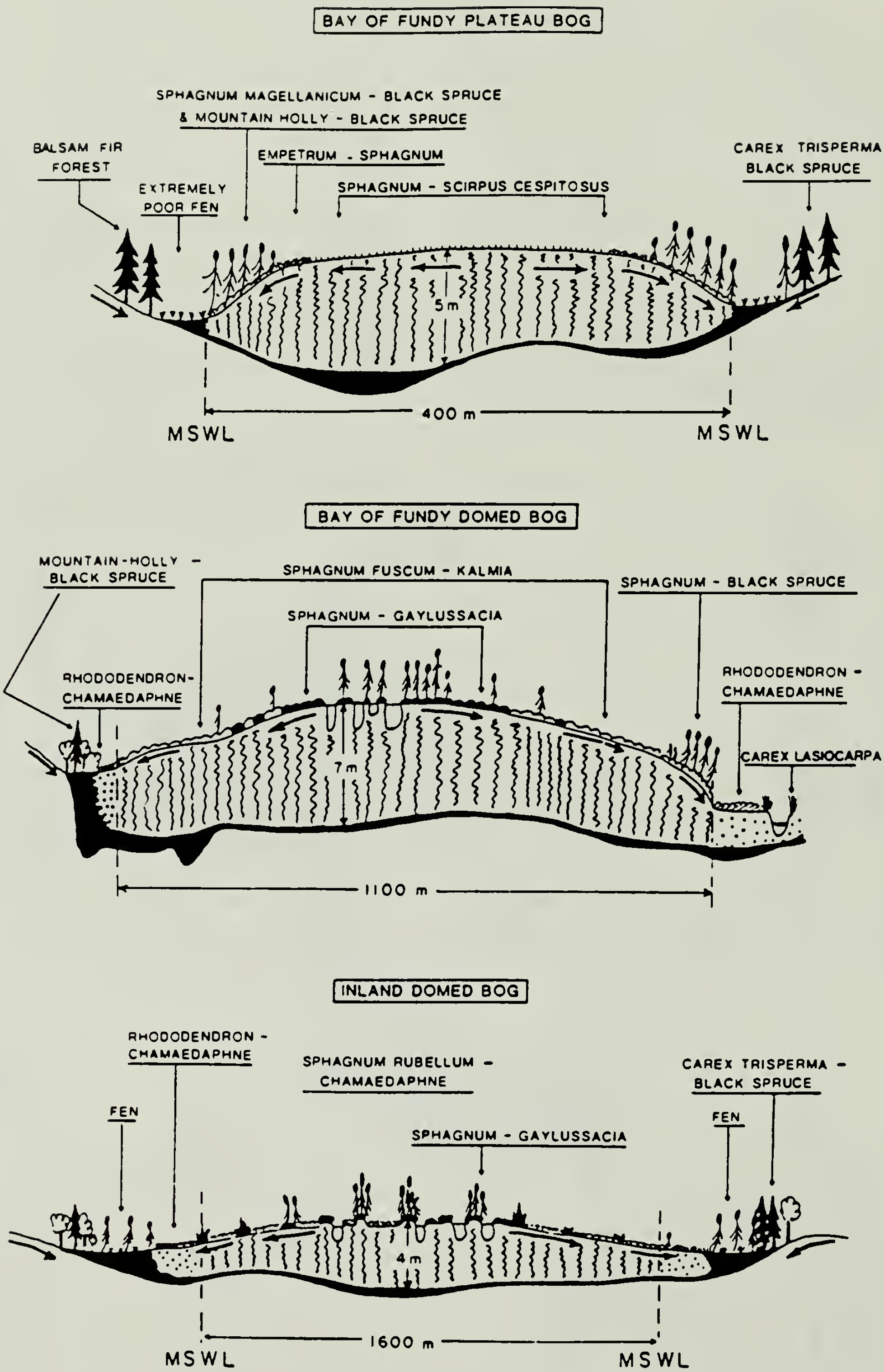


Figure 23. Vegetation pattern in the three major raised bog types of northern New England. The mineral-soil water limit (MSWL) is indicated in all diagrams. The Sphagnum rubellum-Chamaedaphne *community of these bogs is the poor variant with low* Chamaedaphne *typical for ombrotrophic bogs (Damman and French 1987).*

Northern white cedar (Thuja occidentalis) *forested wetlands.* Northern white cedar wetlands occur on both organic and mineral soils. Cradle-and-mound microtopography is most dramatic in the organic wetlands where sphagnum cover may completely blanket the forest floor. Tree species diversity is low, averaging 2–3 species per wetland with canopy heights averaging 9 meters. Subordinate tree species include *Larix laricina, Picea rubens, Picea mariana*, and occasionally, *Acer rubrum*. The shrub layer generally is poorly developed or absent. *Ilex verticillata, Alnus rugosa, Vaccinium corymbosum, Viburnum cassinoides*, currants (*Ribes* spp.), *Spirea latifolia,* and *Rhododendron canadense* may occur, but are not very important and often are restricted to open areas within the forest canopy. Associated herb species are *Symplocarpus foetidus*, bunchberry (*Cornus canadensis*), *Carex trisperma, C. stricta,* manna grass (*Glyceria canadensis* Michx.), *Calamagrostis canadensis,* starflower (*Trientalis borealis*), and Canada mayflower (*Maianthemum canadense*). Seedling species of the dominant shrubs, *Acer rubrum*, and woody species such as *Kalmia angustifolia* and *Vaccinium angustifolium*, which otherwise are not represented, often colonize sphagnum mounds. Prostrate woody species, such as swamp dewberry (*Rubus hispidus*) and *Vaccinium macrocarpon*, often are forest floor components. Woodland orchids such as green wood orchids (*Platanthera clavellata*), green Adder's mouth (*Malaxis unifolia*), and heartleaf twayblade (*Listera cordata*) were found in this forest type.

Northern white cedar wetlands commonly occur in eastern MDI. Good examples can be found west of Route 198 and the outlet of Upper Hadlock Pond as well as on the northeastern shore of Upper Hadlock Pond along the inlet. A mineral soil cedar swamp can be visited on Isle au Haut, just to the north of the beginning of the Long Pond Trail. An exemplary cedar swamp on shallow organic soil can be found to the northwest of Richtown Road in southwestern MDI. As in the swamp on Isle au Haut, a sphagnum carpet with *Carex trisperma* provides a lush green ground cover.

Thuja occidentalis also is found as a codominant with *Picea mariana* and *P. rubens*. Scattered hardwoods, particularly *Acer rubrum*, often are part of the forest canopy. *Nemopanthus mucronata* occurs in this association, but was not seen in the wetlands solely dominated by *Thuja occidentalis*.

A number of rare plants have been found in cedar wetlands. These include *Carex wiegandii* Mackenz. (current record), auricled twayblade (*Listera auriculata* Wieg., last verified 1927), and showy lady's slipper (*Cypripedium reginae* Walt., last verified 1889).

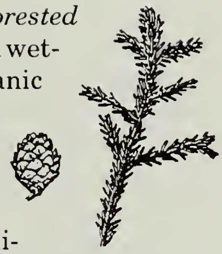
Red spruce (Picea rubens) *wetlands.* Both the composition and the structure of *Picea rubens* wetlands are highly variable because of differences in water regimes and soils associated with this forest type. On the smaller islands associated with MDI (Cranberry Isles, Swans Island, Isle au Haut, for example), *Picea rubens* commonly is found on hillside seeps (wetlands perched on shallow-to-bedrock or till/hardpan slopes) which may have either organic or mineral soils. This community has been found on 0%–15% slopes. Typically, *Picea rubens* is the only tree species and the shrub layer is sparse or absent. A *Sphagnum / Carex trisperma / Symplocarpus foetidus* herb complex is typical. Ferns may be an important part of the herb layer with cinnamon fern (*Osmunda cinnamomea*), bracken fern (*Pteridium aquilinum*), and hay-scented fern (*Dennstaedtia punctilobula*) often present. The moist island climate supports a lush sphagnum moss ground cover typically colonized by spruce seedlings. Red spruce swamps (both hillside seeps with up to 15% slopes and low-lying flat swamps) are transected by the Long Pond and Goat trails on Isle au Haut.

Red spruce wetlands occurring on mineral soil complexes (dominated by a matrix of poorly drained soils interspersed with very poorly drained depressions and somewhat poorly drained "islands") have greater species diversity and better-developed community structure than do those supported by organic soils. Water regimes in any one wetland may range from temporarily flooded to seasonally flooded or seasonally saturated depending on microsite location. Decadent trees and treefall gaps are an important feature of these forested wetlands, as they provide microsite variability. The diverse microenvironments afforded by treefall gaps and varying water regimes and edaphic features tend to produce well-developed tree, shrub, and herb layers. These wetlands are relatively mature forests with open canopies ranging from 15–23 meters in height. *Picea rubens* is the dominant tree species with *Acer rubrum* being a common subdominant. Quaking aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*) also may be present. As many as nine species of tall shrubs may be found in the understory. Distribution is patchy with the thickest concentra-

Figure 24. Mount Desert Island showing areas burned in 1947 (Source: Acadia National Park).

tion of shrubs occurring in treefall gaps. Shrub species include *Viburnum cassinoides,* serviceberry (*Amelanchier* spp.), *Picea rubens*, balsam fir (*Abies balsamea*), *Acer rubrum, Nemopanthus mucronata,* and *Ilex verticillata.* The low shrub community, similarly patchy in distribution, includes *Kalmia angustifolia*, velvetleaf (*Vaccinium myrtilloides*), *Viburnum cassinoides,* and *Vaccinium angustifolium.* Creeping snowberry (*Gaultheria hispidula*) and bearberry (*Arctostaphylos uva-ursi*) dominate the ground cover with *Sphagnum* spp. occurring, often with up to roughly 75% cover, in the wetter pockets. Sphagnum carpets support *Cornus canadensis*, twinflower (*Linnaea borealis*), and goldthread (*Coptis groenlandica*). Other common woodland herbs in this community are *Symplocarpus foetidus, Maianthemum canadense, Carex trisperma, Osmunda cinnamomea*, and *Pteridium aquilinum.* Examples of this community can be seen just north of the beginning of the Hio Road (east of Route 102 just north of the Adam's Bridge) and to the west of the Park Road leaving Schoodic Point.

Red spruce forested wetlands also occur on organic soils, most commonly Bucksport, Wonsqueak, and similar soils. These wetlands are found in valley depressions or isolated depressions in the lowlands. Canopy height ranges from 9–12 meters with *Picea rubens* occurring in almost monotypic stands. Subordinates may include *Acer rubrum* and *Betula papyrifera*. A closed tree canopy results in a poorly developed (or sometimes absent) shrub layer. *Picea rubens* regeneration may or may not occur even if a shrub layer is present. Species diversity is low in these wetlands, particularly as compared to the *Picea rubens* communities established on mineral soils. When a low shrub layer does occur, species associated with shrub fens—*Ledum groenlandicum, Kalmia angustifolia,* and *Acer rubrum*—are often present. Scattered herb associates are *Symplocarpus foetidus, Trientalis borealis,* and *Carex trisperma.* As mentioned above, these wetlands are common on Isle au Haut. Examples on MDI can be found along the easternmost half of the Hio Road as it heads east to the Seawall campground.



Black spruce (Picea mariana) *forested peatlands.* Black spruce forested wetland communities occur on organic soils and typically are associated with other wetland classes such as shrub bogs, shrub fens, or emergent peatlands. *Picea mariana* forests have low tree diversity and may form monotypic stands. *Larix laricina* and *Acer rubrum* may occur as subordinate species, but they are not always present. Tree height averages 9 meters, noticeably less than typical heights in the better-drained forested wetlands. Regeneration of *Picea mariana* in the understory is often absent. However, the understory is well developed and diverse, largely attributable to the pronounced cradle-and-mound microtopography. The tall shrub layer is described by as many as seven species of important shrubs. These include *Nemopanthus mucronata, Rhododendron canadense, Picea mariana, Vaccinium corymbosum, Alnus rugosa, A. crispa, Ilex verticillata,* and *Acer rubrum. Ledum groenlandicum, Gaylussacia baccata, Kalmia angustifolia, Myrica gale,* and *Chamaedaphne calyculata* are present in the low shrub layer. Prostrate woody species such as *Vaccinium macrocarpon, V. oxycoccus,* and *Gaultheria hispidula* typically are present. Sphagnum mosses carpet the forest floor providing a substrate from which grow various herbs. The fern community is dominated by *Osmunda cinnamomea* with royal fern (*O. regalis*) occurring occasionally. Other herbs associated with this wetland community are *Symplocarpus foetidus, Smilacina trifolia, Iris versicolor, Drosera rotundifolia* (these commonly occur in the pools), *Carex trisperma, Trientalis borealis, Sarracenia purpurea, Coptis groenlandica, Maianthemum canadense,* and *Cornus canadensis.* A classic example of this wetland type can be seen bordering Big Heath and along the western edge of a bog in Fresh Meadow which abuts Aunt Betsy's Brook to the west. Northeast of Adam's Brook, just upstream from the Adam's bridge on Route 102, is a good example of an extensive black spruce swamp on acid organic soil. Black spruce wetlands are more common on the western side of MDI and particularly in the landscapes around Bass Harbor Marsh, Fresh Meadow, and the Pretty Marsh Road just south of Route 102.

Picea mariana / Larix laricina forested wetlands occur in mineral and organic soils. The forest floor supports a carpet of sphagnum moss and microtopography is well developed. *Larix laricina* typically occurs in association with other tree species; it rarely occurs in monotypic stands. *Larix laricina* may occur in strips around bogs or fens, but often is under 6 meters tall. Mature larch/spruce wetlands, however, can be found in the moat or lagg around bogs, in isolated depressions, and in valley depressions adjacent to other wetland classes. Occasionally *Acer rubrum* is a subordinate. Typified by an open canopy, the forest overstory is often interrupted by treefall gaps which encourage a diverse understory. The shrub community is well developed. *Viburnum cassinoides* is the only tall shrub found in this mixed forest that is not typically found in pure *Picea mariana* stands, along with regenerating overstory species. The low shrub layer is similar to that described for *Picea mariana* forests. The herb community is characterized by more graminoids—*Carex stricta, C. intumescens, C. trisperma*, Atlantic manna grass (*Glyceria obtusa*), small floating manna grass (*G. borealis*), *Calamagrostis canadensis*, and *Eriophorum virginicum*—than in the pure *Picea mariana* association. Forb and fern composition are similar, however. This community is seen along Route 102A to the north past the Wonderland Trail parking area, along the Hio Road just one-tenth of a mile north of the Seawall Campground, and west of Route 198 soon after the split with Route 3 as one first enters MDI. An example of this community on organic soil (Bucksport) occurs to the southeast of the Richtown Road in Richtown, southwestern MDI.

Hardwood forested wetlands

It is difficult to characterize a typical hardwood system. Wetlands dominated by hardwood trees often display evidence of recent disturbance. Pure stands of *Betula papyrifera* or *Populus tremuloides* colonize areas with recent fire history. (A dramatic example of this occurs northeast of the Sieur de Monts Spring loop parking lot, but visiting the site requires fording a stream across a beaver meadow/shrub swamp associated with Great Meadow). Hardwood-dominated canopies with evergreen understories often point to harvesting of former softwood stands. Evidence of ditching, filling, pasturing, agriculture, and beaver activity is found in many of the hardwood swamps. Further contributing to the difficulty of characterizing a typical hardwood system (with the exception of red maple swamps) is the diversity of hardwood swamp site characteristics: differences in hydrology, nutrient status, and edaphic conditions. A description of red maple swamps and mixed disturbed systems is provided below with the caveat that these systems are highly variable as compared to the softwood forested wetland associations.

Red maple forested wetlands. Forested wetlands dominated by *Acer rubrum* are less common in the Acadia region than they are in southern Maine and the rest of New England. Though red maple saplings and trees often form an outer ring in the lagg of peatlands (particularly in central and northern Maine), and red maple is a common associate of forested wetlands dominated by evergreens, the occurrence of discrete red maple forested wetlands is limited. Those found in the Acadia region occur in low, isolated depressions and on hillside seeps. Soils are generally mineral with water regimes ranging from seasonally saturated to seasonally or temporarily flooded.

An open canopy, abundant treefall gaps, and well-developed structure support a rich plant community. Common subordinate canopy species include *Abies balsamea, Picea rubens, Thuja occidentalis,* yellow birch (*Betula alleghaniensis*), grey birch (*B. populifolia*), *B. papyrifera, Populus tremuloides,* white pine (*Pinus strobus*), and white ash (*Fraxinus americana*). Common associates of the tall shrub layer include *Ilex verticillata, Viburnum cassinoides, Alnus* spp., *Picea* spp., *Thuja occidentalis, Abies balsamea,* and other regenerating canopy species (less often *Acer rubrum*). The low shrub layer—*Kalmia angustifolia, Spirea latifolia,* and *Vaccinium angustifolium*—is typically sparse owing to competition with the dense tall shrub stratum. The herb layer is quite diverse with a number of ferns, graminoids, and forbs thriving in the treefall gaps and along brooks draining the swamp. Ferns, sometimes dominant, include a variety of species: sensitive fern (*Onoclea sensibilis*), New York fern (*Dryopteris noveboracensis*), marsh fern (*D. thelypteris*), *Osmunda cinnamomea, O. regalis*, interrupted fern (*O. claytoniana*), and *Pteridium aquilinum.* Fringed sedge (*Carex crinita*), *C. trisperma, C. intumescens, Glyceria* spp., *Calamagrostis canadensis*, and *Brachyeletrum erectum* (a grass) are common graminoids. Flowering herbs, including *Maianthemum canadense*, Jack-in-the-pulpit (*Arisaema trifolia*), *Aster* spp. (*A. nova-belgii, A. umbellatus,* and others), *Solidago* spp., *Trientalis borealis,* and meadow rue (*Thalictrum polygonum*), are typical. If these wetlands are visited at the right time (this varies with species), orchids, including small purple-fringed orchids (*Platanthera psycodes*), can be discovered.

A red maple swamp on mineral soil and associated with a hillside seep occurs less than 1 kilometer east of the village of Seal Harbor just south of Route 3. Another mineral soil red maple swamp (flat depression) is located in Town Hill on Knox Road to the east of Route 102 (1 kilometer north from that intersection on the west side of the road).

Mixed hardwood-evergreen forested wetlands

These wetlands, occurring on poorly and very poorly drained mineral soils and on organic soils, are highly variable in species composition. Dominant trees vary from an evergreen to a deciduous mix. Floristic structure generally is well developed. The shrub layer is similar to those described for other forested wetlands with the addition of the following species: black cherry (*Prunus serotina*), beaked hazelnut (*Corylus cornuta*), *Aronia melanocarpa*, *Ribes* spp., and northern red oak (*Quercus borealis*). Asters and ferns are often an important component of these mixed forests. Exotic species are more likely to be found in these communities as well. A small disturbed forested wetland occurs next to the Acadia Wild Garden near the Sieur de Monts entrance.

Little research has been conducted on forested wetland ecosystems in the Acadia region. Forest cover types, often including wetland forest designations, were mapped by ANP (1979). Davis (1966) described spruce-fir forests of the coast of Maine; however, these are largely upland sites. The effect of fire on forest composition has been widely studied and may include forested wetland areas. A bibliography of fire literature is available in Greene et al. (1992).

Beaver-impacted wetlands

Beaver have been important in shaping the ecology of the region's wetlands for some time (see Chapters 4 and 8). Damming of streams to create beaver flowages has both altered and created wetland communities. The majority of beaver-impacted wetlands support emergent and/or shrub communities. Flowages that are active or recently abandoned support an herbaceous community dominated by tussock-forming sedges, grasses, aquatic plants, and other herbs. Gilmore Meadows, located near Park Headquarters, is a good example of this type of community. A series of beaver ponds and meadows occurs north of Sand Beach and east of the Precipice.

Carex stricta, C. lacustris Willd., *C. rostrata, C. crinita, Scirpus cyperinus,* and *Calamagrostis canadensis* commonly colonize beaver flowages that have been abandoned or have water levels low enough at some time during the growing season to allow competition with aquatic species such as *Nymphaea odorata, Nuphar variegatum, Pontedaria cordata,* and *Sagittaria* spp. Less common graminoids include *Glyceria canadensis, C. intumescens, C. trisperma, Cladium mariscoides,* and *Dulichium arundinaceum.* Ferns, while present, are not as important as in the hardwood forested wetlands. *Osmunda cinnamomea, O. regalis,* and spinulose wood fern (*Dryopteris spinulosa*) have been noted. Common herbs include *Lysimachia terrestris, Hypericum virginicum,* boneset (*Eupatorium perfoliatum*), grass-leaved goldenrod (*Solidago graminifolia*), narrow-leaved willow herb (*Epilobium leptophyllum*), and *Aster* spp. If the flowage has recently flooded a peatland, pockets of inundated and dying sphagnum moss are present.

Abandoned flowages may support a mosaic of wetland classes representing the various successional stages from deep marsh to forested wetland, including forested, shrub, herb, and open water communities. Common shrubs found in association with the herbs listed above include *Myrica gale, Spirea latifolia, S. tomentosa, Chaemadaphne calyculata, Ilex verticillata, Alnus rugosa,* willows (*Salix* spp.), and *Vaccinium corymbosum.* Snags are abundant in forested wetlands or upland edges suffering long-term flooding. A dramatic example of a beaver-impacted forested site occurs along the western leg of the Witch Hole Pond carriage trail. A snag forest with an understory of meadow and shrubs has developed here.

Woody plants, including both hardwood and softwood species, reclaim abandoned beaver flowages. Often, tree seedlings become established on the sedge tussocks or mounded earth around the dams where drainage is better. As trees and shrubs became established, water levels are lowered through evapotranspiration and a forested wetland community may develop. Examples of these communities are found off the beaten path around Sieur de Monts Springs, in Town Hill, and north of the Bernard Road, west of Route 102.

Rare Plants of Acadia National Park and Vicinity

Rare plants are associated with every wetland system in the Acadia region. A complete list of both documented and historic sightings of rare vascular plants of ANP and the Mount Desert Region was prepared by Greene (1990). Greene (1990) provides information on occurrence, habitat, and status of each species. Occurrence, or likely occurrence, of rare plants in each wetland class is noted in the wetland community descriptions.

Table 14 lists extant obligate and facultative wetland species recorded for ANP. This table includes plants that appear on the state list as well as plants that are watch-listed or locally rare.

Table 14. Rare wetland plants of Acadia National Park.

A. State Listed: Extant Obligate and Facultative Wetland Species*

Species	Supspecies/Variety	Common Name	Status[1]
Bartonia paniculata	subs. *iodandra*	screw-stem	E
Calamagrostis stricta	subs. *inexpansa*	northern reedgrass	T
Carex wiegandii		a sedge	SC
Ilex glabra		inkberry	E
Lomatogonium rotatum		marsh felwort	SC
Montia fontana	subsp. *fontana*	blinks	SC
Spartina x *caespitosa*		marsh cord grass	SC
Subularia aquatica		awlwort	SC
Zannichellia palustris	var. *major*	horned pondweed	SC

B. State Locally Rare or Watch List Extant Obligate and Facultative Wetland Species*

Species	Supspecies/Variety	Common Name	Status[1]
Apios americana		groundnut, wild bean	LR
Arethusa bulbosa		Arethusa, swamp pink	WL
Calla palustris		wild calla	LR
Carex buxbaumii		brown sedge	LR
Carex hystricina		porcupine sedge	LR
Carex oligosperma		few-seeded sedge	LR
Carex pauciflora		few-flowered sedge	LR
Juncus filiformis		thread rush	LR
Juncus greenei		Greene's rush	LR
Lobelia cardinalis		cardinal flower	LR
Menyanthes trifoliata	var. *minor*	buckbean	LR
Mertensia maritima		sea lungwort, oysterleaf	LR
Mitella nuda		naked miterwort	LR
Myriophyllum tenellum		water milfoil	LR
Proserpinaca palustris	var. *crebra*	mermaid weed	LR
Ribes lacustre		bristly black currant	LR
Rubus chamaemorus		cloudberry, baked-apple berry	WL
Scirpus hudsonianus		alpine cotton-grass	LR
Spartina alterniflora		salt-water cord grass	LR
Suaeda linearis		tall seal blite	LR
Symplocarpus foetidus		skunk cabbage	LR
Utricularia geminiscapa		a bladderwort	LR
Verbena hastata		blue vervain	LR
Viburnum recognitum		northern arrrowwood	LR

C. Additional Information on Rare Wetland Plant Species Records in Acadia National Park

Isoetes acadiensis—obligate, collected 1878
Utricularia resupinata—obligate, listed as rare by Rand (1894), not relocated by Greene (1990)
Suaeda americana—obligate, last seen 1892
Suaeda richii—obligate, last seen 1892, was originally collected on Cranberry Isles
Listera auriculata—facultative wetland, last documented 1927
Cypripedium reginae—facultative wetland, last seen 1889
Clethra alnifolia—facultative, listed by Wherry (1928) as rare

Source: Linda Gregory, Acadia National Park (1993).
* Designations according to Reed (1988).
[1] Status designations: E = endangered; T = threatened; SC = special concern; WL = watch list; LR = locally rare

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CHAPTER 7. WETLAND VALUES

INTRODUCTION

Historically, wetlands have been viewed as places of evil and disease. Swamps were traditional hiding places for slaves and criminals; indeed, cedar swamps in New Jersey were routinely burned to flush criminals. Not surprisingly, negative swamp imagery pervades early American literature. This description of the Great Dismal Swamp by David Struther (1856:442), 19th-century raconteur and illustrator, is typical (Figure 25).

> The sky was obscured with leaden colored clouds, and all nature was silent, monotonous, deathlike...walls of matted reeds closed up the view on either side, while thickets of myrtle, greenbriar, bay and juniper hung over the black, narrow canal until the boat could scarcely find a passage between.

This perception of wetlands as wastelands was codified in early legislative acts (e.g., the Swamplands Acts of 1849, 1850, and 1866) which supported the draining and "reclaiming" of these habitats for "more suitable" uses. Between the mid-1950s and the mid-1970s, roughly nine million acres of wetland were converted to nonwetland, particularly agricultural land (Dahl 1990). From George Washington's "Adventurers for the Draining of the Great Dismal Swamp" in 1793 to the U.S. Department of Agriculture's agricultural reclamation projects in the 1950s, wetlands have been perceived as a national burden.

Wetlands continue to generate strong feelings among various groups. Their definition and management are hotly debated issues, polarizing environmentalists against development interests, and industry and private landowners against government regulators.

It wasn't until the 1960s that wetlands began to be better appreciated by society. At that time, scientific studies documenting the importance of coastal wetlands as critical habitats for commercially important finfish catalyzed research of other types of wetland ecosystems. A wide variety of values were documented and consequently wetland protection laws were passed. Since that time, a textbook on wetlands (Mitsch and Gosselink 1986) and a general field guide to North American wetlands (Niering 1985) have been published. As a result of these efforts and others, the American public has been introduced to wetlands as valuable and unique ecosystems.

Figure 25. David Hunter Struther, The Barge. Harper's New Monthly Magazine, *Sept. 1856.*

In this chapter, we give an overview of the major values associated with the Acadia region's wetland ecosystems. This chapter is not intended to be an exhaustive look at generic wetland values; it emphasizes the more important values associated with the region's wetlands as well as some values unique to this region. For a more comprehensive discussion of wetland values, the reader is referred to *Wetland Functions and Values: The State of Our Understanding* (Greeson et al. 1979) and the more popularized texts *Waterlogged Wealth* (Maltby 1986) and *The Future of Wetlands: Assessing Visual-Cultural Values* (Smardon 1983).

Wetlands of the Acadia region traditionally have been used for hunting, trapping, fishing, berry harvest (blueberries and cranberries), timber and salt hay production, peat mining, and livestock grazing. However, with a steadily growing body of wetland research, other wetland values have been recognized as well (Table 15). The values associated with the region will be discussed within the framework of (1) the physical environment, (2) biological values, and (3) human values.

PHYSICAL ENVIRONMENT

Maintenance of Water Quality

Research on the role of wetlands in pollution abatement has shown that a variety of wetland classes retain, remove, or transform pollutants, thereby improving surface water quality (Kadlec

Table 15. List of major wetland values.

Flora and Fauna Values
• Breeding habitat for reptiles and amphibians (vernal pools)
• Fish and shellfish habitat
• Waterfowl and other bird habitat
• Mammal and other wildlife habitat
• Endangered species habitat (plant and animal)
Environmental Quality Values
• Water quality maintenance
• pollution abatement
• sediment removal
• nutrient cycling
• chemical and nutrient absorption
• Aquatic productivity
• Microclimate regulator
• World climate (ozone layer)
Socio-economic Values
• Flood control
• Shoreline erosion control
• Groundwater recharge
• Water supply
• Timber and other natural products
• Energy source (peat)
• Fish and shellfishing
• Hunting and trapping
• Recreation
• Aesthetics
• Education and scientific research

and Kadlec 1979; Brown and Stark 1989; Kadlec and Bevis 1990; Hammer 1990). Wetland soils also may be sinks for nitrate in groundwater (Simmons et al. 1992; Groffman et al. 1991). Contamination of drinking water supplies by nitrate is thought to be the largest remaining water quality problem in the United States and has been linked to human and environmental health threats (Newberry 1992).

Some mechanisms for removing pollutants from waters include seasonal uptake by plants and microbes, long-term storage in woody tissue, sedimentation, adsorption on soil surfaces, and microbial transformations in the biologically active zone of the soil profile (Nixon and Lee 1986; Sposito 1989). Nitrogen and phosphorus associated with agricultural activities, septic systems, or home lawn care are temporarily assimilated by many wetland plants, particularly marsh plants (Grant and Patrick 1970; Thut 1990; Cooper and Hobson 1990).

Forested wetlands, the dominant wetland class in the Acadia region, can be effective in reducing concentrations of nitrogen and phosphorus (Brinson et al. 1981; Kuenzler and Craig 1989). Strips of riparian forests are important in maintaining stream water quality, particularly in areas of intensive agriculture (Jacobs and Gilliam 1985; Peterjohn and Correll 1984). Freshwater wetland soils may reduce 90% of supplemental nitrate to gaseous forms (Bartlett et al. 1979). These findings are supported in more recent research in riparian forested wetlands in Rhode Island where removal of groundwater nitrate was consistently in excess of 80% in both the dormant and the growing season (Simmons et al. 1992; Groffman et al. 1992). Iron and other ions may complex phosphorus to form insoluble chemical compounds (van der Valk et al. 1979; Nixon and Lee 1986). This temporary sink for nutrients (or absolute reduction via transformations) reduces the flush of nutrients to aquatic habitats during the growing season, thereby reducing the risk of eutrophication, or over-enrichment, of the aquatic system during periods of high oxygen demand. Uptake of nitrate by wetlands reduces the risk of exceeding safe drinking water standards in town water supplies including Eagle Lake, Lower Hadlock Pond, Jordan Pond, and Long Pond.

Similarly, heavy metals associated with urban runoff (e.g., nickel, cadmium, chromium, lead, and zinc) may be sequestered in wetland soils and to a lesser extent in the vegetation (Simpson et al. 1983; Good et al. 1975).

Research in other parts of the United States suggests a high potential for removal of pesticides, heavy metals, nutrients, and sediment by hardwood swamps (Winger 1986; Chescheir et al. 1991).

Although wetlands have the potential for ameliorating pollution loads, individual wetlands have a finite capacity for natural assimilation of excess nutrients as plant and microbial pools can become saturated (Good 1982; Aber et al. 1989; Kadlec and Bevis 1990). Capacity of wetlands to filter potential contaminants will also depend on such factors as parent material, hydrogeologic setting, soil type, vegetation, and previous loading history (Groffman et al. 1992). Nutrients may be returned to the wetland system upon senescence of plants and microbes, leaching, and root excretions.

Wetlands also play a valuable role in reducing turbidity of flood waters and reducing siltation of streams and lakes. Streams carrying suspended sediments and dissolved nutrients often overflow into swamps and marshes during flood events. Deposition of sediment occurs at the water-wetland interface where wetland vegetation slows the velocity of water. Suspended particles and adsorbed constituents (heavy metals, pesticides, phosphorus, and other toxins) settle on the wetland surface (Boto and Patrick 1979) as water velocity decreases. Reduction of turbidity is especially important for aquatic life.

Flood Abatement

In their natural condition, wetlands temporarily store flood waters thereby reducing flood peaks and delaying flood crests (Figure 26) (Carter et al. 1979; Novitzki 1982). Excess water from snowmelt or major precipitation events is stored in wetland basins and flood waters are slowed through friction from interaction with wetland plants and soils.

In the Acadia region, the extensive scrub-shrub and marsh wetlands adjacent to streams, lakes, and ponds perform this function. However, no major rivers are associated with MDI or the surrounding islands, and the landscape is relatively undeveloped; this makes major downstream flooding a minor issue in the study area.

Water Supply

Most wetlands are areas of groundwater discharge, and their underlying aquifers may provide sufficient quantities of water for public use. Groundwater depressional wetlands and groundwater slope wetlands are predominantly discharge areas and are valuable in contributing to surface water supplies, in maintaining wildlife habitat, and in diluting open water bodies potentially degraded by excess nutrients or chemicals (Adamus 1986).

Groundwater recharge potential of wetlands varies with wetland type, topographic position, season, soil type, water table location, and precipitation. In general, researchers conclude that most wetlands do not serve as significant groundwater recharge sites (Carter et al. 1979). Wetlands may serve as recharge areas during drier periods (late in the growing season) and if contiguous to streams, may support base flow in streams during periods of drought.

Motts and O'Brien (1981) determined that, on an area basis, about two-thirds of Massachusetts wetlands overlie potential high-yield aquifers. Municipal wells are often located near wet-

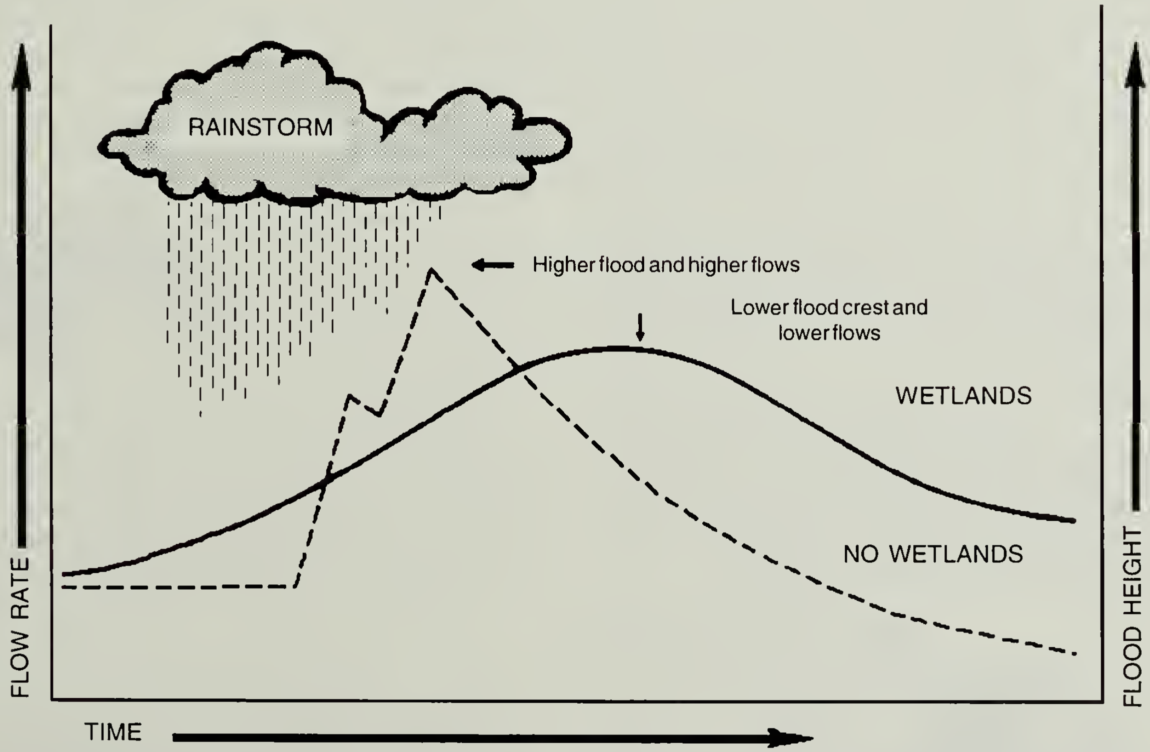


Figure 26. Wetlands help reduce flood crests and slow flow rates after rainstorms (adapted from Kusler 1983).

lands hydrologically linked to groundwater. Therefore, protection of wetlands and their surroundings from pollution should be an integral part of any groundwater management program (Motts and O'Brien 1981). This issue is particularly critical in the Acadia region where four lakes (Eagle Lake, Jordan Pond, Lower Hadlock Pond, and Long Pond) serve as town water supplies. Watershed protection is addressed in ANP's Water Resources Scoping Report (1991).

BIOLOGICAL VALUES

Habitat for Biota

Wetlands have a special role in maintaining the biodiversity of ANP because they provide habitat for a wide diversity of species that fall into three broad groups. First, there are predominantly terrestrial species that can tolerate the wet conditions of a wetland such as white pine (*Pinus strobus*), white-tailed deer (*Odocoileus virginianus*), and garter snakes (*Thamnophis sirtalis*). The second group comprises aquatic species such as mummichogs (*Fundulus* spp.), snapping turtles (*Chelydra serpentina*), otters (*Lutra canadensis*), and water striders (Gerridae) that can survive in the limited pools of water found in wetlands. Some of these facultative terrestrial and aquatic users of wetlands visit wetlands for only a limited time. Spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Rana sylvatica*) visit them to breed in the spring; raccoons (*Procyon lotor*) visit them to forage at night; fish (bluefish and others) visit them at high tide to forage. In other cases, certain members of a population may live permanently in a wetland although most individuals live elsewhere. For example, facultative wetland plants and other sedentary species are found both in wetland and non-wetland environments. Finally, there is a third group of species uniquely associated with wetlands (obligate wetland species) that thrive there and virtually nowhere else: e.g., cattails (*Typha* spp.), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), and pickerel frogs (*Rana palustris*).

The importance of wetlands as habitat for many species is enhanced by the fact that wetlands are relatively undisturbed by people. Thus, they tend to be refugia for species that suffer from contact with people because they are shy or likely to be harvested (shot, caught, or picked).

The wetlands of the Acadia region support a particularly high diversity of species because of their geographic location. Many marine species are present that would not occur at an inland site. Less obvious is the fact that the region lies in a climatic transition zone and thus has both boreal and temperate species (McMahon 1990; Fernald 1916). For example, baked appleberry (*Rubus chamaemorus*), black crowberry (*Empetrum nigrum*), spruce grouse (*Dendragapus candensis*), and palm warblers (*Dendroica palmarum*) are wetland species that are near their southern range limit in the Acadia vicinity, whereas painted turtles (*Chrysemys picta*), inkberry (*Ilex glabra*), and green alder (*Alnus crispa*) are at their northern range limit.

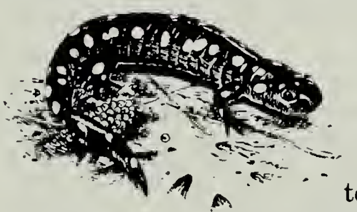
Tallies of the species that occur in wetlands, like those listed in Table 12, do not give a complete picture of wetland value as habitat because some species play more critical roles in ecological systems than others. For example, smooth cordgrass (*Spartina alterniflora*) is a key source of primary production in many estuaries, and beavers can create whole new wetlands. Other species are important for their economic role. Many wetland plants and animals are harvested commercially or by recreationists who pay for the privilege. Even in ANP, where harvesting is generally limited to fish and shellfish, some wild species are more important to the tourism industry than others, and some of these are wetland species—great blue herons, osprey, cranberries, sea lavender, and pitcher plants. Among conservationists, the most important species are usually the rare ones that may be threatened with extinction and need the protection that ANP provides. Species of concern to conservationists are listed in Table 14 for plants and Table 16 for animals and are discussed in Chapters 6 and 8, respectively.

Biodiversity is most easily understood at the species level, but it also includes the diversity of genes found within species and the diversity of ecosystems that species comprise. Little is known about the genetic diversity of wetland species, but it is interesting to speculate that populations that use wetlands facultatively may be genetically different from populations living in other environments. In other words, it is quite likely that the black crowberry or sheep laurel (*Kalmia angustifolia*) living on the top of Cadillac Mountain are genetically different from those living in Big Heath. Similarly, sheep laurel living in beaver

Table 16. Animals considered rare or whose status is unknown who are at least partially dependent on wetlands and may occur in Acadia National Park and vicinity.

Species	Scientific Name	Status[1]
Bald Eagles	*Haliaeetus leucocephalus*	E
Peregrine Falcon	*Falco peregrinus*	E
Piping Plover	*Charadrius melodus*	E
Least Tern	*Sterna antillarum*	E
Roseate Tern	*Sterna dougallii*	E
Harlequin Duck	*Histrionicus histrionicus*	SC
Common Tern	*Sterna hirundo*	SC
Arctic Tern	*Sterna paradisaea*	SC
Black-crowned Night Heron	*Nycticorax nycticorax*	IS
Red Bat	*Lasiurus gorealis*	IS
Hoary Bat	*Lasiurus cinereus*	IS
Silver-haired Bat	*Lasionycteris noctivagans*	IS
Big Brown Bat	*Eptesicus fuscus*	IS
Little Brown Myotis	*Myotis lucifugus*	IS
Keen's Myotis	*Myotis keenii*	IS
Brook Stickleback	*Culaea inconstans*	IS
Barrow's Goldeneye	*Bucephala islandica*	WL
Semipalmated Plover	*Charadrius semipalmalus*	WL
Black-bellied Plover	*Pluvialis squatarola*	WL
Ruddy Turnstone	*Arenaria interpres*	WL
Whimbrel	*Numenius phaeopus*	WL
Greater Yellowlegs	*Tringa melanoleuca*	WL
Lesser Yellowlegs	*Tringa flavipes*	WL
White-rumped Sandpiper	*Calidris fuscicollis*	WL
Least Sandpiper	*Calidris minutilla*	WL
Dunlin	*Calidris alpina*	WL
Short-billed Dowitcher	*Limnodromus griseus*	WL
Semipalmated Sandpiper	*Calidris pusilla*	WL
Sanderling	*Calidris alba*	WL
Bonaparte's Gull	*Larus philadelphia*	WL
Southern Bog Lemming	*Synaptomys cooperi*	WL

[1] E = Endangered species; IS = Indeterminate status; SC = Special concern; WL = Watch list



meadows may be genetically different from that found in shrub fens.

At the ecosystem level of biodiversity, the Acadia region is noteworthy because it contains the southernmost example of a type of ecosystem that is globally rare, the coastal raised bogs described in Chapter 6. Tables 17 and 18 highlight some of the special values of peatlands in general and coastal plateau bogs in particular.

Ecosystem Processes

Many of the values associated with wetland ecosystems are related to wetland functions at a landscape scale. Wetlands interact with the atmosphere, adjacent uplands and nearby wetlands, and with downstream ecosystems. Some key ecosystem processes associated with wetlands in the Acadia region include biogeochemical and hydrological cycling, detritus export, and food web support.

Biogeochemical processes

Wetlands vary in their hydrology (i.e., dominant inputs, outputs, and sources of water), soil and water chemistry, water regime, and degree of human disturbance. Given this and the dynamic nature of biogeochemical processes, it is meaningless to generalize across wetlands. Yet the major processes described below certainly apply to some of the region's wetlands and should be considered important values. These include (1) habitat for microbial transformations including nutrient cycling of such critical nutrients as nitrogen and phosphorus and amelioration of surface water

Table 17. Peatlands as significant natural features.*

- They are distinct ecosystems and hence important contributors to landscape diversity
- In their development, they profoundly modify their local environment, more so than any other ecosystem
- They store organic matter and water
- They act as nutrient sinks and reservoirs
- They contain a record for past millenia of climate, vegetation, and fauna
- They provide open landscape (in a terrain otherwise naturally forested) for various wildlife, notably deer, raptors, mice and voles
- They are habitats for species and communities
    i. that are uncommon or rare
    ii. that often occur in more northerly latitudes
    iii. that are somehow special to people (including orchids, traditional berries such as blueberry, cranberry, huckleberry, and historically baked-apple berry, carnivorous plants, dwarf forests, etc.)

*Adapted from Worley (1980)

acidification through sulfate retention and (2) global carbon reserves.

Microbial transformations

The role of wetlands in nutrient transfer of phosphorus and nitrogen was discussed above as it relates to water quality. Transformation of nutrients, or nutrient cycling, is also an important wetland function. Rates and mechanisms of transfer of nutrients (N, P, K, Ca) among major compartments (soil, air, water, plants) in the wetland are controlled by factors including sources of nutrients, transport into the ecosystem, potential sinks within the wetland, and site conditions (Golet et al. 1992). An overview of key pathways in wetlands can be found in various studies (e.g., Richardson et al. 1978; van der Valk et al. 1979; Nixon and Lee 1986; Bowden 1987).

Microbially mediated nitrogen transformations are among the most important biogeochemical processes in wetlands. One important mechanism for removal of excess nitrate (versus temporary attenuation through plant uptake and immobilization by microbes) is denitrification (the biochemical reduction of nitrate to nitrogen gas). Requirements for biological denitrification include nitrate, a carbon source, and alternately aerobic and anaerobic conditions (Groffman and Tiedje 1989; Groffman et al. 1992)—conditions typical of seasonally flooded, seasonally saturated, and tidal wetlands. Wetlands have a greater potential for

Table 18. Significance of Coastal Plateau Bogs of Maine*

As unique geomorphological features

- Coastal Plateau Bogs are rare in North America, found only in limited coastal areas of New Brunswick, Nova Scotia and Newfoundland (and possibly along the North Pacific Coast)
- They are raised bogs; the only clearly raised bogs in the United States east of the northern Lake States are in Maine
- They are at the southern limit of raised bogs in eastern North America, and include some of the southernmost raised peatlands in North America
- They are the most maritime raised bogs in the United States
- They include an outstanding example of variation in peatland types along an ombrotrophic to minerotrophic gradient
- They have the southernmost raised bog pond system in the eastern United States, probably in all the US (Big Heath)

As sites of unique geologic processes

- They include the only ombrogenic peatlands in the United States being eroded by tidewater, a phenomenon rare in North America, otherwise only known from limited locations in extreme maritime Atlantic Canada
- They have the only example in the eastern US with a marine beach being deposited upon a raised peatland

As unique biological features

- They are the only raised peatlands in the eastern United States where minerotrophic species such as skunk cabbage (*Symplocarpus foetidus*) and common juniper (*Juniperus communis*) grow on ombrotrophic peats
- They have the southern limit of lowland habitat for baked-apple berry (*Rubus chamaemorus*) and black crowberry (*Empetrum nigrum*), important species of the Northern Hemisphere in higher latitude ecosystems
- They include the southern limit of the *Empetrum nigrum-Sphagnum fuscum* and *Scirpus cespitosus-Sphagnum fuscum* communities
- They apparently have the greatest diversity of species of raised peatlands in the eastern United States
- They, because of their cranberries, have provided local place names, including the name of a township

* Adapted from Worley (1980) (For a complete list of unique features of coastal plateau bogs see pp. 130–133 in Worley [1980])

microbial nitrate attenuation through denitrification than do non-wetland sites (Groffman et al. 1992).

Nitrogen-fixation, a microbially mediated process that converts atmospheric nitrogen to an organic form available to other biota, may be important in wetlands including minerotrophic peatlands (Waugham and Bellamy 1980). Schwintzer (1983) reported an addition of 3.53 g $N/m^2/yr$ in an oligotrophic Maine bog. Given the extent of peatlands in the Acadia region, plants associated with nitrogen-fixing microorganisms (e.g., *Myrica gale, Alnus* spp.) may be an important link in the nitrogen cycle.

Sulfate cycling is also an important microbial process in wetlands. Both terrestrial and aquatic ecosystems are subject to excess loading of sulfate and nitrate through acid deposition. Influx of sulfate and nitrate can lead to decreased soil pH and leaching of nutrients (Brinson 1991). Current research identifies wetlands as important ecosystems in ameliorating the impacts of acid rain (Spratt and Morgan 1990; Urban et al. 1989). Nutrient cycling by microbes and plants may retain sulfur in the wetland, preventing excess sulfate from entering open waters. Organic forms of sulfur may be active forms for sulfur cycling in peatlands and may be an important sink for anthropogenic sulfate (Spratt and Morgan 1990).

Research on the role of wetlands in sulfur cycling has been limited in the Acadia region. Kahl et al. (1983) studied Duck Pond (associated with a small wetland) and waters draining Great Meadow near Sieur de Mont Springs. Their data regarding sulfur dynamics and the role of wetlands in changing surface water chemistry were inconclusive and may be obfuscated by additional inputs of sulfate from dry deposition and marine aerosols (J.S. Kahl, University of Maine, pers. comm.) However, data from other studies conducted in northeastern North America suggest wetlands may be an important sink for sulfate. Poor fens in Canada retained up to 73% of supplemental sulfate loading, preventing acidification of export water (Bayley et al. 1986). Urban et al. (1989) found 58% of sulfate inputs retained within peat deposits. Both are within the range reported for bogs throughout the Northeast (Urban et al. 1989).

Carbon reservoirs

In the past 10 years, peatlands in the northern temperate, boreal, and subarctic regions have been recognized as key components in the global carbon cycle (Gorham 1991). The amount of carbon in the global peat reservoir is estimated to be 450 Pg (10^{15} g) with an annual increase of 0.2 Pg (Brown et al. 1989) or 20–100 g C m^2/yr (Armento and Menges 1986). Peatlands are a net sink for carbon dioxide as carbon is stored in the peat as organic matter. Gorham (1991) describes the role of northern peatlands in the reversal and acceleration of carbon exchange as related to global warming. He estimates if peat ceased to accumulate worldwide and instead decomposed at a rate of 1 centimeter annually due to falling water tables initiated by global warming, the two Pg of carbon released worldwide would be equal to one-third of the current annual carbon release from fossil fuel consumption and similar to that released by deforestation. Drainage of peatlands for peat mining or development could have the same impact.

Peatlands make up a significant portion of the wetlands of the Acadia region and hence may play a significant regional role in carbon sequestration. Brinson (1991) considers peatlands carbon conservation areas and argues that although temperate peatlands are a small resource relative to boreal and subarctic wetlands, they are valuable carbon reserves. The cumulative impact of their loss could be globally significant.

Even though the role of peatlands in carbon cycling and global warming is still uncertain, the resource is a valuable component of that cycle as these wetlands are both a source (methane) and a sink (carbon dioxide) for two important greenhouse gases.

Detritus export and food web support

Some wetlands transform inorganic carbon and nitrogen to organic forms accessible to a wide variety of biota. Brinson et al. (1981) have shown that rivers draining watersheds with extensive areas of bordering wetlands contain more organic material than rivers in watersheds without wetlands. Waters draining undisturbed peatlands are low in inorganic nutrients and high in organic carbon and organic nitrogen. Dissolved organic carbon concentrations for waters draining peatlands in the Acadia region have values significantly higher than waters draining upland habitats (J.S. Kahl, University of Maine, pers. comm.). Organic carbon export (particulate and dissolved) may serve as an energy source for consumers in adjacent riverine or lacustrine systems. Although a large percentage of organic materials are refractory, they potentially support a large number of bacteria that use this dissolved and particulate matter (Tranvik and Sieburth 1989) and in turn support other organisms.

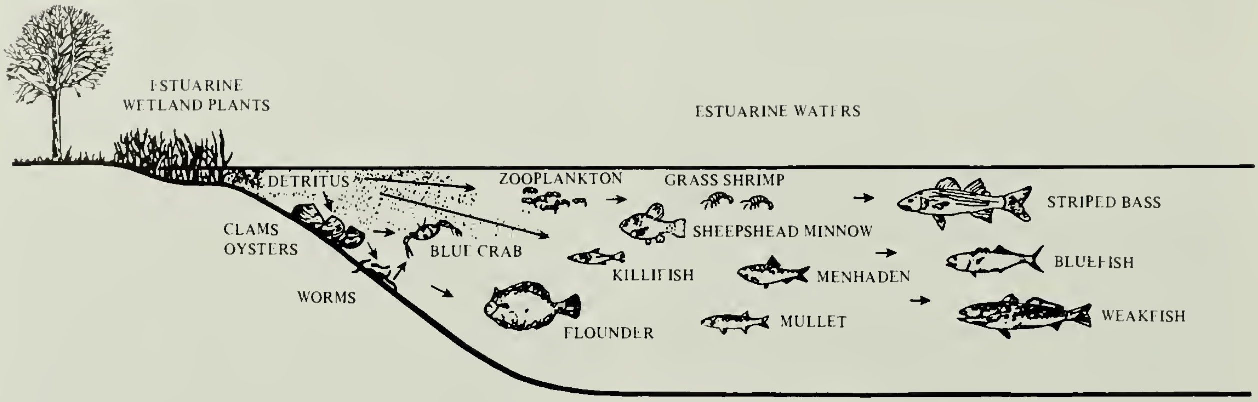


Figure 27. Simplified food pathways from estuarine vegetation to commercially and recreationally important fishes and shellfishes.

Similarly, detritus (decayed organic material) from salt marshes supports an estuarine food web closely linked to the productivity of marine life (Crow and MacDonald 1979). A simplified food web for estuaries in the Northeast is presented in Figure 27.

HUMAN VALUES

Economic Values

Aside from the economic value of wetlands associated with the above wetland functions, wetlands produce a variety of natural products and resources including timber, fish, and shellfish. Only fish and shellfish are of direct commercial significance at this time. Fisheries data for several ponds are available from Fuller and Cooper (1946). Several of the "Great Ponds" (ponds over 4 hectares) are managed by the Maine Department of Inland Fisheries and Wildlife for a variety of sport-fish species including lake trout (*Salvelinus maycush*), native brook trout (*Salvelinus fontinalis*), landlocked salmon (*Salmo salar*), and brown trout (*Salmo trutta*) (NPS 1991). Ecologically and economically the intertidal mud flats of the Acadia region are extremely valuable. Fefer and Schettig (1980) provide an excellent overview of the diverse invertebrate populations of coastal Maine mud flats and their importance to shorebirds, gulls, wading birds, and waterfowl. Commercial harvest of soft-shelled clams (*Mya arenaria*) and bait worms (sand worm—*Nereis virens*) is particularly prevalent on intertidal mud flats of the area. There is only limited industrial logging in the Acadia region, although logging was common in the 1800s, largely in upland habitats. Black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*), and tamarack (*Larix laricina*)—all occurring in the region's forested wetlands—are considered of significant commercial value, but are rarely commercially harvested.

Aesthetic and Cultural Values

ANP is one of the most visited national parks in the United States, with an estimated 2.7 million visitors each year. Recreational opportunities in and around wetlands including fishing, shellfishing, berry picking, wildlife observation, canoeing, photography, outdoor education, and botanizing—all factors in the overall attraction to ANP and vicinity.

In a less obvious way the region's wetlands are important in providing, to the discerning eye, a living record of the natural and human history of the region. Climate and plant community changes since the retreat of the last glacier are preserved in the pollen and macrofossils in peatlands. Vestiges of ditches and fences, a record of the attempt to adapt wetlands to pasture and other agricultural uses, as well as the presence of exotic species (e.g., purple loosestrife [*Lythrum salicaria*]) and shell middens, all reveal human interaction with a delicate environment over the years. Delight and pride in the Acadia region, of which wetlands are a vital part, is reflected in such descriptive names as Cranberry Isles, Seal Cove, and Bass Harbor Marsh.

Values without measure—those of beauty and wildness—can be defined only by the individual. The Acadia region provides ample opportunity for reflection on this value. Although not always flashy or dramatic, wetlands mark the seasons with distinct floral displays. The purple bloom of rhodora anticipates leaf-out in the spring, while sea lavender lends a purple cast to coastal marshes. The transient blooms of the bog orchids in the summer reward the patient observer. Flashy and dramatic may well describe wetlands in fall. The scarlet of the red maple swamps stands in sharp contrast to the green leaves of the upland trees still clinging to summer. The peatlands ablaze with the maroons and reds of the ericaceous shrubs; the mosaic of browns and golds of the saltmarsh herbs punctuated by the brilliant reds of saltwort all mark the arrival of autumn. Later, festive red berries against silver branches decorate winter wetlands as winterberry wards off the gloom of the short, dark November days and conveniently persist throughout the holiday season.

The wetlands of the Acadia region are diverse and contribute significantly to the health, productivity, and uniqueness of the region. We still have much to learn about the functions of these ecosystems, but what knowledge we have demonstrates that these habitats are worthy of our protection and of our respect.

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CHAPTER 8. WETLAND FAUNA OF ACADIA NATIONAL PARK AND VICINITY

WATERFOWL AND OTHER BIRDS

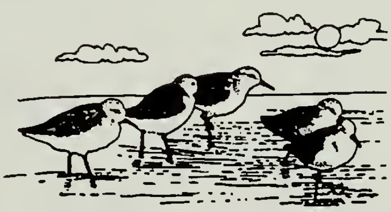
In Chapter 6 we alluded to the importance of wetlands as habitat for plants and animals. Indeed, wetlands, because of their variety, complex vegetative structure, and mixture of wet and dry habitats, contain a rich diversity of both vertebrate and invertebrate species. Below we outline some of the important wildlife assemblages located in the wetlands of the Acadia region.

Spectacular concentrations of American eider ducks (*Somateria mollissima*), numbering in the thousands, can be found off Schoodic Point in the fall, and adjacent to many offshore islands such as Isle au Haut during the winter. Smaller groups can be found all along the coast. On falling tides, large flocks of scoters, primarily white-winged (*Melanitta fusca*), as well as eiders move to submerged blue mussel (*Mytilus edulis*) bars for feeding. An excellent location to view feeding waterfowl is at the bar between Bar Island and Bar Harbor as eiders and scoters are often joined by greater scaup (*Aythya marila*), goldeneyes (*Bucephala clangula*), red-breasted mergansers (*Mergus serrator*), buffleheads (*Bucephala albeola*), and oldsquaws (*Clangula hyemalis*). Eiders and scoters feed primarily on mussels, urchins (*Strongylocentrotus droebachiensis*), and green crabs (*Carcinus maenas*) (Korschgen 1976), while the other species consume small fish, amphipods (*Gamnimarus oceanicus*), isopods (*Idotea baltica*), small clams (*Mya arenaria*), and periwinkles (*Littorina* spp.). All are reaping the benefits of food items found in sub- and intertidal marine wetlands. Joining these species during winter are common loons (*Gavia immer*), horned grebes (*Podiceps auritus*), and black guillemots (*Cepphus grylle*).

Intertidal estuarine wetlands of Frenchman and Blue Hill bays are important wintering areas for black ducks (*Anas rubripes*). An excellent viewing spot for this species is at the picnic area on Thompson Island. Average mid-winter waterfowl inventory figures for Frenchman and Blue Hill bays are given in Table 19.

Wintering harlequin ducks (*Histrionicus histrionicus*) congregate along the south shore of Isle au Haut and nearby islands to the east. This concentration represents the remaining major portion of the western Atlantic population of this species which has been declared endangered in eastern Canada and is a species of special concern in Maine. Brant geese (*Branta bernicla*) are found on a limited number of offshore islands during their spring migration, grazing on new green shoots as well as feeding in the intertidal zone (P. Corr, Maine Dept. Inland Fisheries and Wildlife, pers. comm.).

Offshore islands are important nesting sites for eiders, herring (*Larus argentatus*) and black-back (*Larus marinus*) gulls, arctic (*Sterna paradisaea*) and common (*Sterna hirundo*) terns, black guillemots, and double-crested cormorants (*Phalacrocorax auritus*). All of these species depend heavily on marine and estuarine wetlands for food.



A variety of shore birds, including semipalmated (*Calidris pusilla*) and least (*Calidris minutilla*) sandpipers, greater (*Tringa melanoleuca*) and lesser (*Tringa flavipes*) yellowlegs, and semipalmated (*Charadrius sempalmatus*) and black-bellied (*Pluvialis squatarola*) plovers feed extensively on invertebrates of mudflats (Fefer and Schettig 1980) during the fall to accumulate fat reserves for their long flight to Central and South America. These coastal areas are referred to as staging areas and include roosting as well as feeding sites. Several important sites on and adjacent to MDI include Goose Cove near the MDI causeway, Duck and Mitchell coves, Bass Harbor Marsh, the flats north of Bar Harbor, and flats associated with Great Scott and Great Cranberry Islands.

Coastal salt marshes such as Bass Harbor Marsh provide excellent habitat for a variety of shore birds and great blue herons (*Ardea herodias*), as well as black ducks, mallards (*Anas platy-rhynchos*), and blue- (*Anas discors*) and green-winged (*Anas crecca*) teal. Passerine species inhabiting these areas include red-winged blackbirds (*Agelaius phoeniceus*) and marsh wrens (*Cistothorus palustris*). Gibbs et al. (1987) noted that the size of coastal great blue heron colonies

Table 19. Average mid-winter waterfowl inventories for Frenchman and Blue Hill bays.

Species	Frenchman Bay 1988–1992	Blue Hill Bay 1980–1983
eiders	8,400	20,300
scoter	1,000	2,100
goldeneye	1,500	1,100
black duck	1,900	400
bufflehead	400	500
oldsquaw	300	1,200

Source: Patrick Corr, Maine Department of Inland Fisheries and Wildlife, pers. comm.

corresponded closely to area of wetlands available within a 20-kilometer radius of the nesting colony. Five nesting colonies of herons, ranging from 5 to 130 nesting pairs, are located on islands between Schoodic Point and Isle au Haut.

Wetlands on MDI are also used by bald eagles (*Haliaeetus leucocephalus*), ospreys (*Pandion haliaetus*), and northern harriers (*Circus cyaneus*). Gibbs et al. (1991) found all three species to be area-sensitive, preferring larger than smaller wetlands (eagle >5 hectares, osprey and northern harrier >1 hectares). Suitable wetlands for all three species are found on MDI, and eagles have historically nested in habitats associated with the Bass Harbor estuary as well as in wetlands adjacent to Northeast Creek.

Inland freshwater marshes are used by a variety of birds including waterfowl, wading birds, rails, and songbirds. Great Meadow, Fresh Meadow and Bliss Field are major freshwater wetlands on MDI providing waterfowl habitat (NPS 1991). Palustrine emergent marshes bordered by stands of flooded timber have very high avian species richness (Owen, unpubl. data) including true aquatic species, as well as a variety of cavity nesters, blackbirds, wrens, flycatchers, and warblers.

Forested wetlands provide habitat for a variety of species including the saw-whet (*Aegolius acadicus*) and barred (*Strix varia*) owls, sharp-shinned hawk (*Accipiter striatus*), woodcock (*Scolopax minor*), veery (*Catharus fuscescens*), northern waterthrush (*Seiurus noveboracenis*), yellow-rumped (*Dendroica coronata*) and black and white (*Mniotilta varia*) warblers, and white-throated sparrow (*Zonotrichia albicollis*). Complex peatlands such as Big Heath, composed of a variety of wetland classes, contain a wide diversity of avian species (S. Stockwell, Maine Audubon Soc., pers. comm.). Three unusual species found in Big Heath are the Lincoln's sparrow (*Melospiza lincolnii*), palm warbler (*Dendroica palmarum*), and spruce grouse (*Dendragapus canadensis*).

MAMMALS, REPTILES AND AMPHIBIANS

Wetlands on MDI are used by a diverse group of furbearers, including beaver (*Castor canadensis*), muskrat (*Ondatra zibethica*), otter (*Lutra canadensis*), mink (*Mustela vison*), red fox (*Vulpes fulva*), coyote (*Canis latrans*), weasel (*Mustela* spp.), and raccoon (*Procyon lotor*). The dominant mammal is the beaver whose dam building has been instrumental in creating or modifying many palustrine wetlands on MDI. Because of intense trapping, beaver were extirpated from MDI by the early 1900s. Four individuals were reintroduced to the island in 1921, but numbers remained low until after the 1947 fire which burned much of the eastern half of MDI (Figure 24). Regenerating aspen stands created ideal beaver habitat, and their populations expanded rapidly, reaching nearly 300 by the late 1970s (Mueller-Schwarze 1979) and necessitating control measures by NPS personnel. Recent surveys indicate that the beaver population has declined to approximately 100 individuals (ANP files). NPS management policies (NPS 1991) encourage natural processes to function unimpeded to the greatest extent possible. Under that scenario successional changes will likely dictate further declines in beaver and their associated wetlands on MDI. Beaver were instrumental in transforming MDI's rather short, steep watersheds into a mosaic of wetlands, slowing flows, retaining runoff, and capturing sediments. These wetlands provide habitats for a variety of wetland species.

One species, the otter, demonstrates the importance of beaver-created wetlands. Dubuc et al. (1990) noted that otter were closely associated with these wetlands, feeding on amphibians, fish, and insects and occupying abandoned beaver lodges and dams as den sites. Due to the increased food availability for beaver some 45 years after the 1947 fire, beaver, as well as otter, are more prevalent on the eastern half of MDI.

Otter also demonstrate an interesting link between fresh and marine wetlands. Dubuc et al. (1991) showed that otter travel regularly between these habitats using small streams as travel corridors. In winter, otter feed extensively on marine fishes such as mummichogs (*Fundulus heteroclitus*) and cunners (*Tautogolabrus adspersus*) (Dubuc et al. 1991) and perhaps are partially filling the niche of the extinct sea mink (*Mustella macrodon*) known to occupy Maine's coast during aboriginal times (Sanger 1989).

Other mammals occupying wetlands include snowshoe hares (*Lepus americanus*), red (*Tamiasciurus hudsonicus*) and flying (*Glaucomys sabrinus*) squirrels, meadow (*Microtus pennsylvanicus*) and boreal red-backed (*Clethrionomys gapperi*) voles, shorttail (*Blarina grevicauda*) and masked (*Sorex cinereus*) shrews, and meadow jumping mice (*Zapus hudsonius*). White-tailed deer (*Odocoileus virginianus*) numbers also increased rapidly after the 1947 fire, and these animals use wetlands for feeding and resting. Several northern white cedar swamps still show the impact of winter browsing by deer. Bats, a nocturnal equivalent of swallows, can be observed feeding over ponds and marshes.

Besides mammals and birds, a variety of other forms of wildlife make their homes in wetlands. Reptiles (i.e., turtles and snakes) and amphibians (i.e., toads, salamanders, and frogs) are important residents. DeGraaf and Rudis (1983) described the non-marine reptiles and amphibians of New England including their habitat and life history. Turtles recorded from MDI wetlands include the eastern painted (*Chrysemys picta*), snapping (*Chelydra serpentina*), and musk (*Sternotherus odoratus*) turtles, the former a relatively recent (30 years) arrival

(Rhodin 1991), the latter an uncommon species (Manville 1939). Several species of snakes, the northern red-bellied (*Storeria occipitomaculata*), eastern garter (*Thamnophis sirtalis*), ringneck (*Diadophis punctatus*), and smooth green (*Opheodrys vernalis*), frequent wetlands and have all been observed on MDI and several of the larger offshore islands (e.g., Isle Au Haut and Swans Island). Amphibians recorded only for MDI include the American toad (*Bufo americanus*), gray treefrog (*Hyla versicolor*), bullfrog (*Rana catesbeiana*), wood frog (*Rana sylvatica*), leopard frog (*Rana pipiens*), two-lined salamander (*Eurycea bislineata*), and the rare four-toed salamander (*Hemidactylium scutatum*). Amphibians observed on both MDI and Swan Island are the spotted salamander (*Ambystoma maculatum*), red-spotted newt (*Notophthalmus viridescens*), spring peeper (*Pseudacris crucifer*), green frog (*Rana clamitans*), and pickerel frog (*Rana palustris*) (Hunter et al. 1992).

An unusual number of state and federally listed wildlife species are associated with wetlands (Table 16). Although many of these species are associated with the mainland, the importance of wetlands to their existence cannot be overemphasized.

FISH AND INVERTEBRATES

Estuarine Fish

Estuarine plant communities that fringe the many embayments and coves of the Acadia region provide essential habitat for fishes. Fish use salt marshes, submerged aquatic beds, rocky shores, and other areas for spawning, nursery areas, or refuge from predators. They may be resident populations, anadromous, catadromous, or transients. Both Bigelow and Schroeder (1953) and Fefer and Schettig (1980) have assembled the most comprehensive review of species occurrence, geographical distribution, habitat preference, and life history strategies for the fishes that frequent the Maine coast. Other, more ecosystem-specific studies of estuarine fishes in the Gulf of Maine region have been conducted in the Great Bay estuary (Short 1992), Wells Harbor (Ayvazian et al. 1992), Sheepscot River estuary (Targett and McCleave 1974), and Passamaquoddy Bay (MacDonald et al. 1984), to name only a few. Comprehensive estuarine fish surveys on MDI have not been conducted, although a study in Bass Harbor Marsh is currently ongoing (C.T. Roman, NPS, pers. comm.). Based on these studies, the fishes common to estuarine habitats of the Acadia region will be described.

Common mummichogs (*Fundulus heteroclitus*), four-spine sticklebacks (*Apeltes quadracus*), and nine-spine sticklebacks (*Pungitius pungitius*) are perhaps the most abundant residents—species that spend their entire lives in the estuary. Salt marshes, tidal creeks, and eelgrass beds are a favorite habitat for these residents. The Atlantic silversides (*Menidia menidia*) are also quite common. Silversides spawn in the estuary, often depositing eggs on intertidal *Spartina*. The juveniles and adults use the estuary as a nursery throughout the summer and into fall, then migrate offshore in winter (Conover and Ross 1982).

American eel (*Anguilla rostrata*), the only catadromous species in Maine estuaries, spawns in the ocean. Young eels (elvers) then migrate to quiet estuarine or freshwater habitats where they develop into adults. Anadromous species, common to the estuaries of the region, include alewife (*Alosa pseudoharengus*) and to a lesser extent, blueback herring (*Alosa aestivalis*). The adults migrate to freshwater ponds in spring to spawn. The juveniles then use estuarine waters as nursery habitat before migrating into deeper coast waters in late fall.

Perhaps the most common value of estuaries, as reported in the popular literature, relates to the nursery function for economically important fish. Atlantic herring (*Clupea harengus*), the most important commercial finfish in Maine waters (Fefer and Schettig 1980), are often found in estuarine waters during summer. Other commercially important species that frequent estuarine habitats during a portion of their life cycle include winter flounder (*Pleuronectes americanus*), white hake (*Urophycis tenuis*), pollack (*Pollachis virens*), and Atlantic menhaden (*Brevoortia tyrannus*), to name only a few. The ecological importance of estuarine fishes is equally important as the economic value. The mummichogs, alewives, silversides, and others all provide an essential prey item for wading birds, osprey and eagles, seals, and fishes of higher trophic levels.

Freshwater Fish

The clear, cold lakes and ponds on MDI and Isle au Haut are home to a variety of freshwater fishes. The shallow waters, marshes, lake outlets, and tributaries are used by fish for spawning and as nurseries as well as a source of food (Tiner 1989). Salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) spawn in these areas by digging a depression in the gravel where eggs are deposited and fertilized. Other species like the smelt (*Osmerus mordax*) and alewife, important foods for the salmonids, use these same areas. Warmwater species such as the smallmouth bass (*Micropterus dolomieui*) and sunfish (*Lepomis* spp.) move into the aquatic wetland sites to breed and feed. In these species the male remains to guard the nest and young, whereas the chain pickerel (*Exox niger*), another MDI resident, offers no parental care for the young (Migdalski and Ficter 1983).

Much of the interest in freshwater fishes has focused on recreational fishing. Although water quality is good to excellent in many of the fresh waters within the study area, fishing pressure, coupled with low primary productivity, has necessitated continued stocking of game fish and food fish like the alewife. The earliest records of fish stocking date back to the 1890s when landlocked (Atlantic) salmon were introduced into Eagle Lake (Newlin 1989). Brook trout, lake trout (togue) (*Salvelinus namaycush*), landlocked salmon, and brown trout (*Salmo trutta*) are the coldwater species that are currently stocked.

There have been sporadic inventories of freshwater fishes on MDI (Fuller and Cooper 1946) and in Long Pond on Isle au Haut (Manville 1964) with the most recent in 1984 (Maine Department of Inland Fisheries and Wildlife).

Invertebrates

A tremendous variety and number of invertebrates occupy wetlands. Some of these species feed on live plants, but most consume dead organic matter, and others are predators. Table 20 lists the functional groups of aquatic insects and their feeding habits. Figure 28 illustrates their interrelationships in an aquatic ecosystem. Invertebrates, because of their enormous numbers and biomass, provide the food base for the many vertebrate species frequenting wetlands. Procter (1946) carried out a monumental study of the insects of MDI in the 1930s. Adult forms of many aquatic species were recorded. Recently White (1989) commented on the dragonflies and damselflies of ANP, and Mack and Gibbs (1991) reported on the mayflies in ANP. The latter noted the paucity of species in marsh, pond, and lake habitats as compared to stream habitats. To date there are no known state or federally listed invertebrate species on MDI.

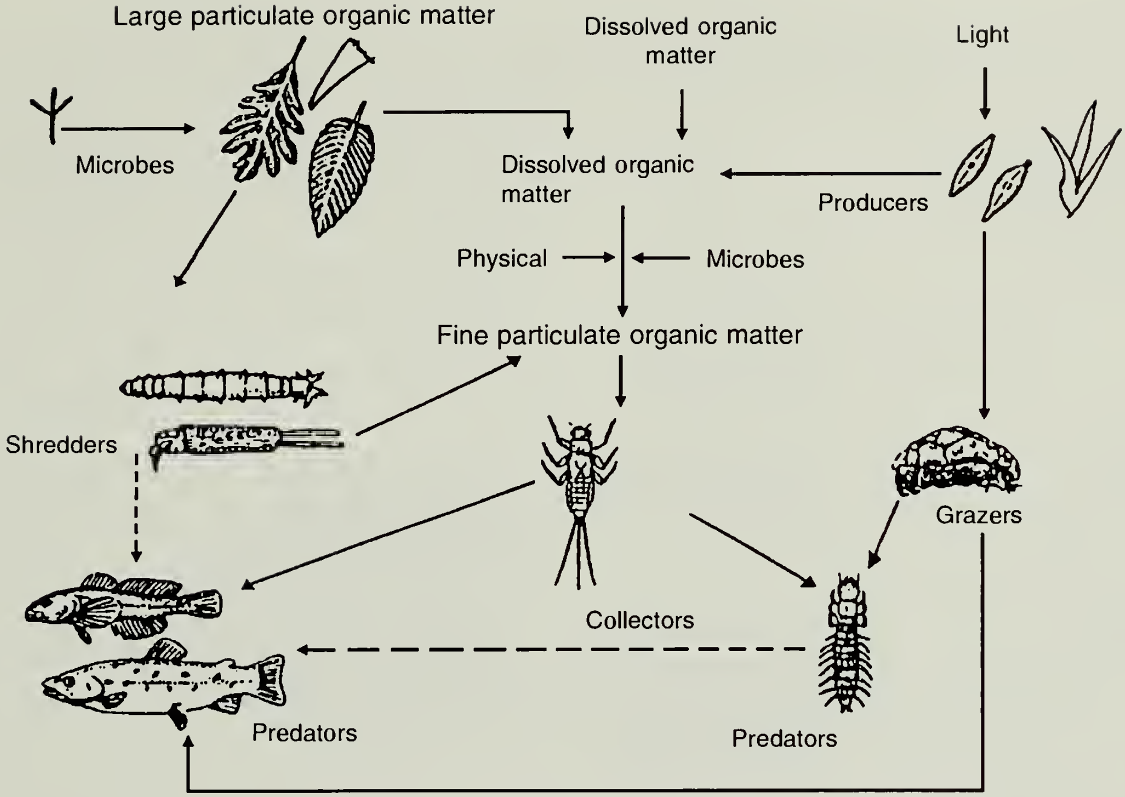


Figure 28. Food chain relationships in an aquatic ecosystem (Cummins 1974).

On a final note, MDI and the other islands along Maine's coast probably exhibit lower faunal diversity than on the mainland. A tenet of Island Biogeography Theory (MacArthur and Wilson 1967) proposes that species diversity declines as a function of island size and distance from the mainland. Although this theory was developed for oceanic islands, Crowell (1986) documented a decrease in mammalian fauna occupying several islands, including MDI, in the Penobscot Bay region compared to the adjacent mainland. Decreases in other faunal or floral assemblages on MDI and associated islands may also reflect similar relationships.

Table 20. Functional groups of aquatic insects, their foods and feeding mechanisms. (From Merritt, R.W., and K.W. Cummins. 1984. *An Introduction to the Aquatic Insects of North America.* Copyright 1984 by Kendall/Hunt Publishing Co. Used with permission.)

Functional Group (General category based on feeding mechanism)	Subdivision of Functional Group: Dominant Food	Subdivision of Functional Group: Feeding Mechanism	General Particle Size Range of Food (microns)
Shredders	Living vascular hydrophyte plant tissue Decomposing vascular plant tissue-coarse particulate organic matter (CPOM)	Herbivores—chewers and miners Detritivores—chewers and wood borers	>10^3
Collectors	Decomposing fine particulate organic matter (FPOM)	Detritivores—filterers or suspension feeders Detritivores—gatherers or deposit (sediment) feeders (includes surface film feeders)	<10^3
Scrapers	Periphyton-attached algae and associated material	Herbivores—grazing scrapers of mineral and organic surfaces	<10^3
	Living vascular hydrophyte cell and tissue fluids or filamentons (microscopic) algal cell fluids	Herbivores— pierce tissues or cells and suck fluids	>10^2–10^3
Piercers	Living animal tissue	Carnivores—attack prey and pierce tissues and cells and suck fluids	>10^3
Engulfers (Predators)	Living animal tissue	Carnivores—whole animals (or parts)	>10^3
Parasites	Living animal tissue	Internal parasites of eggs, larvae and pupae. External parasites of larvae, prepupae and pupae in cocoons, pupal cases, or mines. Also, external parasites of adult spiders.	>10^3

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CHAPTER 9. WETLAND PROTECTION

INTRODUCTION

A variety of techniques are available to protect our remaining wetlands, including strict implementation of land-use regulations, direct acquisition, conservation easements, tax incentives, and public education. Kusler (1983) describes these techniques in great detail in *Our National Wetland Heritage—A Protection Guidebook.* Opportunities also exist for private initiatives by individual landowners, groups, and corporations to help in conserving wetlands. Private options for land preservation are reviewed by Rusmore et al. (1982).

WETLAND REGULATIONS

Several federal and state laws regulate certain uses of Maine wetlands. Most significant are the Rivers and Harbors Act of 1899 and the Clean Water Act of 1977 at the federal level, and the Maine Natural Resources Protection Act of 1990 at the state level. In addition, Executive Order 11990—Protection of Wetlands—requires federal agencies to develop guidelines to minimize destruction and degradation of wetlands and to preserve and enhance wetland values. Key points of these and other laws are outlined in Table 21.

To affirm its commitment to conserving wetlands, the Clinton Administration has announced its intention to issue a new Wetlands Protection Executive Order in 1994. The order will embrace the interim goal of no overall net loss of the nation's remaining wetlands resource base, and the long-term goal of increasing the quality and quantity of the nation's wetlands (White House Office of Environmental Policy 1993). Federal agencies will be directed to take a watershed/ecosystem approach to wetland protection and restoration. The NPS will then revise its wetland guidelines to incorporate such changes. Table 22 highlights current guidelines for floodplain management and wetlands protection in national parks.

The foundations of federal wetland regulation are Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. Section 10 of the Rivers and Harbors Act requires that a permit be obtained from the Army Corps of Engineers (Corps) for the dredging or filling of navigable waters or the construction of obstacles to navigation such as piers, breakwaters, and weirs (DiSilvestro 1985). Navigable waters extend to the mean high-tide line in coastal areas and to the normal high-water line in rivers, thus both coastal and riverine wetlands may be affected. A 1958 amendment to the Fish and Wildlife Coordination Act required consultation between the Corps and the USFWS, and by 1968 the Corps included factors such as fish and wildlife conservation, pollution, aesthetics, and public interest in its permit review process.

Enacted in 1972 as part of the Federal Water Pollution Control Act and amended during reauthorization of the Clean Water Act of 1977, Section 404 regulates the discharge of dredged or fill material into the waters of the United States, including wetlands. The goal of the Clean Water Act is to "restore and maintain the chemical, physical and biological integrity of the Nation's water." The Section 404 program helps achieve these goals by preventing significant or unnecessary losses of wetlands and other sensitive aquatic areas. By the late 1970s and early 1980s, several important court decisions and an improved understanding of wetland values mandated an enhanced role for Section 404 in wetland protection.

Many construction activities in the waters of the United States involve some discharge of dredged or fill material and thus require a Section 404 permit. Construction of marinas, highways, residential and industrial developments, dams and bulkheads, and stream relocations fall under the purview of the program. Other activities that do not involve direct filling but also degrade waters of the United States, including excavation activities (ditching, channelization, and mechanized clearing of land), also fall under 404 jurisdiction. "Waters of the United States" reach to the furthest extent permissible under the Commerce Clause of the Constitution and include rivers, lakes, streams, ponds, and wetlands (e.g., swamps, marshes, sloughs, bogs, and fens).

Three main elements must be present to establish Section 404 jurisdiction: (1) the activity in question must involve a discharge of dredged or fill material; (2) the discharge must be from a point source; and (3) this discharge must occur in waters of the United States. In many cases determining jurisdiction is straightforward, but in some circumstances, difficulties in delineating the limit of waters of the U.S., or uncertainty about whether a particular activity involves a discharge of dredged or fill material, complicate the task. Clarification by the federal agencies of the definition of "discharge of fill material" is in progress.

The U.S. Environmental Protection Agency (EPA) and the Corps share program responsibilities under Section 404. The Corps administers the program on a day-to-day basis and acts on permits. EPA developed the Section 404(b)(1) guidelines in conjunction with the Corps. These regulations must be applied by the Corps in evaluating permit applications. In addition, the Corps has its own permit regulations which are used to review projects. Furthermore, EPA has authority under Section 404(c) to veto Corps-issued permits based on a determination of "unacceptable adverse impacts" to certain environmental resources. Congress also assigned EPA the responsibility for approving assumption of the program by qualified states. Both EPA and the Corps have authority to enforce against unauthorized discharges and violations of permit conditions. The USFWS, however, is the lead agency of the Department of the Interior for wetland and Section 404 issues/compliances in ANP.

Section 404 contains certain limited exemptions. Congress exempted normal ongoing agricultural and silvicultural activities such as plowing and harvesting of crops or timber, and certain types of maintenance activities. However, Congress was careful not to exempt discharges associated with activities causing major disruptions of wetlands or other aquatic resources (e.g., clearing, diking, and leveling a forested wetland for cranberry production).

Section 404(f)(2) provides that "any discharge incidental to one of the activities listed in Section 404(f)(1) that results in a change in use of the waters of the United States, and which impairs the flow or reduces the reach of waters of the United States requires a permit." Thus, discharges from activities exempted by Section 404(f)(1) can be "recaptured" by Section 404(f)(2) and become subject to permit requirements.

Over the last several years the federal agencies and courts have narrowly construed the Section 404(f)(1) exemption. In several recent cases the courts found that farming activities either were not part of an established operation or that they were a new use that "reduced the reach of the wetlands" in question. As a result, these activities were not exempt under Section 404(f)(1) or they were "recaptured" by Section 404(f)(2) and required Section 404 permits.

The Corps can issue either individual or general permits. Individual permits are processed upon receipt of a complete permit application and are subject to public notice and comment on the proposed work. A number of boilerplate conditions normally apply to all permits. Special conditions may also be included for a specific activity. Nationwide, general permits are granted for a number of activities that the Corps believes have minimal individual and cumulative adverse environmental effects. The District or Division Engineer of the Corps may also issue general permits called "regional permits" within a particular geographic area. This region may encompass a watershed drainage area, a state, or an entire Corps Division. Regional permits may be conditioned to require a case-by-case reporting and acknowledgment system. For Maine, a state program general permit is currently in effect. Additional information about this permit is available from the New England District of the Corps in Waltham, Massachusetts.

The USFWS, the National Marine Fisheries Service, and the Maine Department of Inland Fisheries and Wildlife all play important roles in the Section 404 process. The Fish and Wildlife Coordination Act requires that the Corps consult with these agencies whenever an applicant seeks a Section 404 permit. When reviewing Section 404 permits these agencies recommend measures to protect fish and other wildlife resources. Further, the Coastal Zone Management Act (1972) requires that the Corps receive a consistency determination from the state coastal zone management program before issuing some permits. In addition to implementing its own program, Maine has the authority through Section 401 of the Clean Water Act to issue, condition, waive, or deny water quality certification for federal permits and licenses. No Section 404 permit may be issued unless the state grants or waives Section 401 certification. Any conditions that the state makes as part of a Section 401 certification must be included in the Section 404 permit.

Currently, the Section 404 Regulatory Program in Maine is more active and controversial than ever. Although there is still interest in the regulation of coastal development and harbor management planning, greater emphasis is now placed on inland wetland development. Unless an applicant is certain that a proposed wetland activity qualifies for a "nationwide permit," the Corps requires a review of all applications in Maine, as well as a Section 404 permit for the proposed activity. In addition, the Corps may require or propose alternative use and/or compensation for certain projects. The EPA has conducted "Advanced Identification of Sites" in southern Maine to determine guideline standards for wetlands of concern. These changes, coupled with a more active interagency review, have strengthened federal regulation over Maine's wetlands.

Another federal law affecting Maine's wetlands is the 1985 Farm Bill. This bill includes the

Table 21. Summary of primary federal and state laws relating to wetland protection in Maine.

Name of Law	Administering Agency	Type of Wetlands Regulated	Regulated Activities
Rivers and Harbors Act of 1899 (Section 10)	U.S. Army Corps of Engineers	Tidal wetlands below the mean high water mark	Structure and/or work, including dredging and filling, in or affecting navigable waters of the U.S.
Clean Water Act of 1977 (Section 404)	U.S. Army Corps of Engineers under their regulations and 404(b)(1)	All wetlands as defined by the 1987 Delineation Manual (Environmental Laboratories 1987).	Discharge of dredged or fill material.
Food Security Act of 1985 Swampbuster Provision 1990 Amendment	U.S. Department of Agriculture	All wetlands as defined by the 1987 Delineation Manual (Environmental Laboratories 1987).	Any wetland conversion resulting in increased agricultural production on wetlands.
Natural Resources Protection Act (NRPA) of 1990	Maine Department of Environmental Protection	Coastal wetlands, freshwater wetlands larger than 10 acres, wetlands associated with great ponds, or wetlands in the floodplain of any river, stream, or brook. Maine's NRPA divides wetlands into 3 classes based on the "value" of specific functions such as floodwater storage, wildlife habitat, and groundwater recharge. Class I wetlands are of highest value because of their biological functions such as habitat for threatened or endangered plants, unique natural community, or significant wildlife habitat. Class II wetlands are important largely because of their hydrologic functions such as protection of water quality and control of flood waters. Many of these wetlands include, or are located near, open waterbodies or water courses, but also include peatlands and wetlands containing >20,000 sq. ft. of aquatic vegetation, emergent marsh vegetation, or open water. The remaining wetlands, e.g., wooded swamps and wet meadows, are considered Class III wetlands.	All activities that are in, on or over any protected wetland or are on land adjacent to any wetland such that material or soil may be washed into it. Activities include: dredging, bulldozing, removing or displacing soil, sand, vegetation or other materials; draining or otherwise dewatering; filling; and any construction, repair, or alteration of any permanent structure.

Table 21. Continued.

Exemptions	Comments
None specified	July 22, 1982 Regulations: U.S. Fish and Wildlife Service and Maine Department of Inland Fisheries and Wildlife review permit applications for environmental impacts by authority of Fish and Wildlife Coordination Act.
Normal farming, silviculture and ranching activities (including minor drainage); maintenance of existing structures; construction or maintenance of farm ponds or irrigation ditches; construction of temporary sedimentation basins; construction or maintenance of farm roads, forestry roads, or temporary mining roads (within certain specifications).	July 22, 1982 Regulations: U.S. Environmental Protection Agency oversight, U.S. Fish and Wildlife Service, and Maine Department of Inland Fisheries and Wildlife review proposed work for environmental impacts by authority of the Fish and Wildlife Coordination Act. Permits cannot be issued without state certification that proposed discharge meets state water quality standards. Individual permits are required for specific work in many wetlands; regional permits for certain categories of activities in specified geographic areas; nationwide permits for 25 specific activities and for discharges into wetlands above headwaters or those which are not part of surface tributary systems to interstate or navigable waters of U.S. State takeover of permit program is encouraged. New regulations were issued in October 1984.
Any non-agricultural use as well as cranberry production, orchards, and shrub and tree plantings.	
Neither functional assessment nor compensation is required for: minor alteration in coastal wetlands or great ponds (Class I wetlands) providing there is no impact on marine resources, wildlife, or aquatic habitat; alteration work in Class II and III wetlands along existing transportation routes which impact less than 20,000 sq. ft., or alterations of wetlands for a road, rail or utility line crossing a river, stream, or brook for a distance of up to 100 ft. from the normal highwater line. Forest management activities are permitted in Class II and III wetlands, and any class wetland may be drained for growing an agricultural crop.	An analysis of alternatives must be considered before any activity occurs in Class I and II wetlands or in Class III when more than 20,000 sq. ft. are impacted. In Class I and II wetlands, the only projects permissible are those necessary for: health and safety, crossings by road, rail or utility lines, water dependent uses, expansion of a facility because of its relation to an existing facility and mineral excavation and related facilities. A hierarchy of alternatives must be considered including avoidance, minimal alteration, and compensation. Compensation values are based on a wetland's classification. Mitigation banking is permissible.

Table 22. Highlights of wetlands guidance outlined in the NPS's floodplain management and wetlands protection guidelines.

1. Parks are required to inventory wetlands resources as part of the planning process (General Management Plan) or subsequent planning documents, prioritize inventory on development zones and other natural zones where wetland impacts are most likely to occur.

2. Parks are required to avoid any action with the potential for adversely impacting wetlands where there is a "practicable alternative." (Such adverse impacts may result from actions in wetlands, from actions external to wetlands but still having impacts upon them, or from actions which otherwise, directly or indirectly, support wetland development.)

3. Where no such practicable alternatives exist (including "no action"), proposed actions must be designed or modified so as to preserve and enhance natural and beneficial values of wetlands, and must minimize, through mitigation, their destruction, loss, or degradation.

4. Through the Natural Resources Management Plant/WRMP process, parks are required to restore wetland functions and values where they have been harmed by human disturbance.

5. NPS Resource Management Plans and/or Water Resources Management Plans must specify requirements for monitoring programs and other actions necessary to ensure protection, enhancement, or successful restoration of wetlands values to the greatest extent feasible.

6. GMP must include an inventory of existing structures, facilities, and programs involving the use of wetlands, and record decisions on their retention, removal or modification.

7. Changes to the National Environmental Policy Act (NEPA) process where adverse impacts to wetlands are not avoidable:

   a. Statement of Findings attached to NEPA Finding of No Significant Impact or final environmental impact statement compliance with NPS Floodplain Management and Wetlands Protection Guidelines;

   b. No actions are "categorical exclusions";

   c. Public review periods are lengthened.

swampbuster provision designed to discourage farmers from converting wetlands to production of commodity crops (Chandler 1988). Farmers who drain wetlands are ineligible for any USDA benefits they might receive under the Farm Bill. Agriculture is the number one cause of wetland destruction in the United States, and the swampbuster provision is an attempt to stem this loss.

State regulation of wetlands in Maine began in 1967 with adoption of the Coastal Wetlands Alteration Act. However, it was almost 20 years before freshwater wetlands received any consideration by the state. In 1985 an Act to Protect Freshwater Wetlands was passed, and in 1988 most regulations dealing with natural resources were consolidated into the Natural Resources Protection Act.

Specific regulations defining wetland classes and their conservation were promulgated under the Wetland Protection Rules of 1990; minor amendments to the Rules are anticipated in 1993. Under these rules wetlands are classified as Class I, II, or III based on their values and functions (Table 9.1). Levels of protection and mitigation requirements vary according to the classification of a wetland. Only wetlands 10 acres or greater are regulated by the state of Maine.

Maine towns may obtain the permit-granting authority for wetlands provided they have adopted a comprehensive plan and related landuse ordinances and have the financial, technical, and legal resources to review and analyze applications as well as enforce permit requirements. Local ordinances may be stricter than state or federal laws. To date, no municipalities on MDI have requested this authority. Therefore, all towns must interact with the state.

WETLAND ACQUISITION

Wetlands may also be protected by direct acquisition or by other techniques such as conservation easements. Although many wetlands are owned by public agencies or environmental organizations throughout coastal Maine, the majority are still privately owned. In response to the needs of local landowners and as fee acquisitions for wetlands become increasingly expensive and often politically sensitive, the negotiation of conservation easements has become popular in recent years.

ANP and the Maine Coast Heritage Trust have been especially successful in protecting ecologically sensitive areas through the purchase of conservation easements. The National Park System conservation easement program for ANP began in 1970 and ANP now owns or holds easements on a significant amount of coastal and freshwater wetlands in the MDI-Schoodic region. In total, ANP administers 148 easements, the largest number for a single unit within the National Park System.

Other agencies protecting wetlands in the Acadia region are the Maine Department of Inland Fisheries and Wildlife, Maine Bureau of Public Lands, Maine Department of Parks and Recreation, the Nature Conservancy, National Audubon Society, and several local land trusts. In addition, there are 3 National Wildlife Refuges along the coast of Maine: the Moosehorn NWR at Cobscook Bay in eastern Maine, the Petit Manan NWR with holdings adjacent to ANP, and the Rachel Carson NWR south of Portland. All three refuges are important in protecting estuarine and marine wetlands and their associated species.

FUTURE ACTIONS

Many opportunities are available to both government and private sectors to significantly reduce wetland losses. Their joint efforts will determine the future of our nation's wetlands. Major options are outlined below. For a more detailed discussion the reader is referred to Kusler (1978, 1983), Burke et al. (1989), and Rusmore et al. (1982).

Government Options

1. Develop a consistent public policy to protect wetlands of national and state significance.
2. Strengthen federal, state, and local wetland protection measures.
3. Ensure proper implementation of existing laws and policies through adequate surveillance and enforcement.
4. Identify wetland areas of significant value and increase wetland acquisition in selected areas.
5. Remove government subsidies that encourage wetland drainage or other wetland alterations.
6. Provide tax and other incentives to private landowners and industry to encourage wetland preservation.
7. Scrutinize cost-benefit analyses and justifications for flood control projects that involve channelization of wetlands and watercourses.
8. Improve wetland management on public-owned lands.
9. Increase the number of marsh restoration projects. This should include enhancing existing wetlands by improving local water quality.
10. Establish buffer zones around wetlands.
11. Monitor wetland changes with special attention to the effectiveness of state and federal wetland protection efforts and periodically update wetland inventories in problem areas.
12. Increase public awareness of wetland values, regulations, and the status of wetlands using the various media.
13. Conduct research to increase our knowledge of wetland values and to identify ways of using wetlands that are least disruptive to their ecological and public values.

Private Options

1. Rather than drain or fill wetlands, seek compatible uses of those areas: timber harvest, waterfowl production, fur harvest, hay and forage, wild rice production, and hunting leases, for example.
2. Donate wetlands to private or public conservation agencies.
3. Maintain wetlands as open space.
4. When selling property that includes wetlands, consider incorporating into the master transfer a deed restriction, or covenant, preventing future alterations and destruction of the wetland, and an appropriate buffer zone.

5. Work in concert with government agencies to inform the public about wetland values.
6. Purchase federal duck stamps to support wetland acquisition.
7. Support various public and private initiatives (e.g., contribute funds, conservation easements) to protect, enhance, and conserve wetlands.

Robichaud and Buell (1973) raised four basic questions which are central to the fate of the natural environment:

1. How much future population growth?
2. What future industrial growth?
3. How much and what kind of open space?
4. Who plans and controls land use?

The eventual answers to these questions will determine the future quantity and quality of Maine's wetlands. Robichaud and Buell (1973) recognized that people must develop a land ethic—an appreciation for the value of land in its natural state. To reach this endpoint the public must be informed of the impacts associated with different land uses. For example, they must understand that filling and developing wetlands and floodplains leads directly to downstream flooding problems, as well as other losses such as wildlife habitat. Public education is therefore vital to protecting wetlands. Such private nonprofit organizations as the Maine Coastal Heritage Trust, the Natural Resources Council of Maine, the Maine Audubon Society, the Maine Nature Conservancy, and others have made major contributions to educating the public on wetlands and other natural resources. ANP plays a key role in this effort for the Acadia region.

Both at the national and state levels, wetland conservation continues to be a volatile, divisive topic. Delineation procedures are being challenged as well as state and federal regulations. In Maine, competition for wetlands has been particularly intense between developers and environmental agencies and organizations. Ways must be found to achieve economic growth while minimizing adverse environmental impacts. This is vital to preserving wetland values for future generations.

Future Resource Issues to Be Addressed in Acadia National Park

As evidenced from this report, many technical studies have been conducted on wetlands in ANP and vicinity. Development of a database on the status, functions, and processes of these valuable ecosystems must continue in order that effective scientifically based resource protection activities can be pursued. The discussion that follows is not all-inclusive, yet it does serve to highlight some research, inventory, and monitoring needs linked specifically to issues affecting ANP.

Baseline ecological inventories

The ongoing study of the Bass Harbor Marsh ecosystem is successfully developing a baseline of information on habitat utilization by fish and benthos, water quality trends and processes, and aquatic vegetation dynamics. This study was initiated in response to specific concerns regarding observed trends in the status of the marsh trout fishery, increases in aquatic vegetation, and nutrient inputs from adjacent land uses. Similarly an ecological assessment of the Northeast Creek tidal marsh system is needed so that long-term monitoring programs can be designed and implemented, enabling resource managers to evaluate ecosystem status and to quantitatively document responses to natural or human-induced impacts. The Northeast Creek-Fresh Meadow system and associated watershed, located on the northern part of MDI, are mostly in private ownership. Given the potential for increased residential development, it is important to inventory nutrient inputs, fish, benthos, and wildlife use as well as wetland vegetation dynamics.

Other wetland complexes would benefit from comprehensive baseline inventories, including Big Heath, Great Meadow, and Gilmore Meadow. Further biological assessments of lakes and ponds are clearly necessary. For example, few recent inventories of the freshwater fish of ANP have been conducted.

The wetland-human interface

Wetlands are a common feature of the Acadian landscape. Because of this, human impact on these ecosystems is inevitable. Steps should be taken, however, to make this a positive relationship. Suggestions toward realizing this goal are listed below.

- Evaluate the impact of intensive urchin harvesting and mussel digging in the subtidal wetlands associated with the Acadia region.
- Evaluate both visitor/resident impact on water quality and wetlands. For example, is there evidence of water quality/wetland

degradation in heavily used sections of ANP? Do landuse activities inside/outside ANP boundaries have a negative or potentially threatening impact on these resources?

- Evaluate the relationship between wetlands and water supply. Is there an association between wetland distribution and aquifers? If so, are the wetlands adequately protected? How are the wetland resources linked to major surface water supplies and how do they affect water quality?

- Evaluate needs of sensitive ecosystems. Attractive wetlands, particularly Big Heath, have come to the attention of the public as unique areas to visit. The potential for damage from visitation to this and other vulnerable ecosystems is high. Construction of boardwalks on popular bog and marsh sites and further development of interpretative programs on wetland ecosystems would protect fragile habitats and heighten public awareness of the positive attributes of waterlogged habitats.

Knowledge gained on these issues can then be constructively channeled into policies and practices that encourage a healthy relationship between the people of the Acadia region and its wetland resources.

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APPENDIX 1. DETAILED SOIL DESCRIPTIONS

MATERIALS AND METHODS

The soil information specific to the study area was collected mostly by qualitative field characterization. Initially, soil profiles were observed at 3 to 20 sites for each of the Acadia region's major wetland classes for which soil information is relevant. In many cases, the soils were described simultaneously with the vegetation communities and any recurring correlations were noted.

After several similar soils were observed in the study area, a representative profile was described. All soils were classified according to the Keys to Soil Taxonomy (Soil Survey Staff 1992). Established soil series (USDA Soil Conservation Service [A] 1986, 1987, 1988, 1991, 1992) were used to standardize the soils observed in the study area to other areas.

Soils were excavated using a tiling spade and a bucket auger. Soil colors were described according to the Munsell Soil Color Charts. Textures were estimated in the field and samples were rechecked later by moistening and hand-estimating texture parameters.

Reactions were measured only for classification purposes and were derived using a soil reaction (pH) tester checked against pH standard solutions. They are given in the descriptions as ranges, so as not to imply greater accuracy than is warranted. The following standard categories are used (Soil Survey Staff 1981):

	pH
extremely acid	< 4.5
neutral	6.6–7.3
very strongly acid	4.5–5.0
mildly alkaline	7.4–7.8
strongly acid	5.1–5.5
moderately alkaline	7.9–8.4
moderately acid	5.6–6.0
strongly alkaline	8.5–9.0
slightly acid	6.1–6.5
very strongly alkaline	> 9.0

Typifying pedons for all but the Wonsqueak soil are described below. (The word "pedon" is used here loosely to mean soil sampling unit.) Soil characteristics outside the range for the established series are listed. The typifying pedon for the official Wonsqueak series description is 2000 feet (610 meters) northwest of Baldwin Corners in the town of Tremont on MDI, and was used in this report (USDA Soil Conservation Service 1992) and was not revisited during this study.

BIDDEFORD TAXADJUNCT TYPICAL PEDON

Classification: fine-loamy, mixed, nonacid, Histic Humaquept

Location: southeast then northeast along private driveway that leaves Route 102 just north of Adams Bridge, to gray house; then east 0.4 km along woods road and National Park Service boundary; about 5 meters south of the boundary line.

Date described: 9/9/91; JEC.

Physiography: glaciomarine sediment basin.

Parent Material: glaciomarine sediments.

Slope: less than 1%.

Microrelief: cradle-and-mound; pedon described in a cradle.

Drainage: very poorly drained; free water at 7 cm from the top of the Oe horizon on the date described.

Vegetation: evergreen forested wetland.

Major root zone: to 15 cm.

Remarks: description is from field observations.

Oe—0 to 7 cm; black (10YR 2/1) on broken face and when crushed, mucky peat (hemic material); about 75% fiber, about 60% rubbed; massive; very friable; extremely acid; abrupt, wavy boundary.

Oa—7 to 33 cm; black (10YR 2/1) on broken face and when crushed, muck (sapric material); about 15% fiber, about 10% rubbed; weak fine granular structure; very friable; extremely acid; abrupt, wavy boundary.

Eg—33 to 100 cm; dark gray (5Y 4/1) and very dark gray (5Y 3/1) silty clay; very sticky and very plastic; very strongly acid.

BCg—100 to 110 cm; dark bluish gray (5B 4/1) clay loam; sticky and plastic; neutral.

2Cg—110 to 140 cm; greenish gray (5GY 5/1) loam; slightly sticky and slightly plastic; moderately alkaline.

Established series: this pedon is outside the range of characteristics for the Biddeford established series (USDA Soil Conservation Service [A] 1991) because it is extremely acid in the surface and moderately alkaline in the substratum. Also, the texture is clay loam in the subsoil and loam in the substratum. No mottles were observed, possibly due to the use of the bucket auger.

BUCKSPORT TYPICAL PEDON

Classification: euic, Typic Borosaprist.
Location: Adams Brook, about 1.3 km upstream from Adams Bridge, hummocky area on the west side of the brook.
Date described: 6/27/91; JEC, AJC.
Physiography: low-lying area along defined drainage-way.
Parent Material: organic deposits.
Slope: less than 1%.
Microrelief: cradle-and-mound; pedon described in a cradle.
Drainage: very poorly drained; free water at 8 cm from the top of the Oi horizon on the date described.
Vegetation: scrub-shrub fen.
Major rooting zone: to 100 cm.
Remarks: description is from field observations with a bucket auger.

Oi—0 to 8 cm; very dusky red (2.5YR 2/2) on broken face and when crushed, peat (fibric material); about 80% fiber, about 70% rubbed, about 3% coarse woody fragments; massive; very friable; many very fine, few fine, and common medium roots; extremely acid; clear, wavy boundary.

Oe—8 to 37 cm; dark reddish brown (5YR 2/2) on broken face and when crushed, mucky peat (hemic material); about 75% fiber, about 30% rubbed, about 3% coarse woody fragments; massive; nonsticky and slightly plastic; many very fine, few fine, and common medium roots; extremely acid.

Oa1—37 to 100 cm; dark reddish brown (5YR 2/2) on broken face and when crushed, muck (sapric material); about 3% fiber, about 2% rubbed; few black (N 2/0) charcoal fragments; massive; slightly sticky and slightly plastic; common very fine roots; very strongly acid.

Oa2—100 to 133 cm; dark brown (7.5YR 3/2) on broken face, muck (sapric material), black (5YR 2/1) when crushed; about 7% fiber, about 5% rubbed; massive; nonsticky and slightly plastic; few very fine roots; moderately acid.

Oa3—133 to 160 cm; very dark brown (10YR 2/2) on broken face and when crushed, muck (sapric material); about 5% fiber, about 3% rubbed; massive; slightly sticky and slightly plastic; few very fine roots; strongly acid.

Established series: this pedon fits the range of characteristics for the Bucksport established series (USDA Soil Conservation Service [A] 1991).

IPSWICH TAXADJUNCT TYPICAL PEDON

Classification: euic, frigid, Typic Sulfisaprist.
Location: in the Mitchell Cove Marsh, west of the paved road about 30 meters.
Date described: 9/10/91, JEC.
Physiography: brackish water-inundated lowland.
Parent material: organic deposits.
Slope: less than 1%.
Microrelief: nearly flat with slightly depressed pannes; pedon described outside of pannes.
Drainage: very poorly drained; described at low tide, though the pannes were filled with water, and free water was at 6 cm from the surface of the Oe horizon when described.
Vegetation: salt marsh.
Major rooting zone: to 24 cm.
Remarks: description is from field observations with a bucket auger.

Oe—0 to 24 cm; very dark brown (10YR 2/2) on broken face and when crushed, mucky peat (hemic material); about 50% fiber, about 25% rubbed; weak fine granular structure; very friable; root bound with very fine roots; mildly alkaline; abrupt, smooth boundary.

Oa—24 to 160 cm; dark reddish brown (5YR 2/2) on broken face and when crushed, muck (sapric material); about 15% fiber, about 10% rubbed; massive; nonsticky and slightly plastic; mildly alkaline.

Established series: this pedon is outside the range of characteristics for the Ipswich established series (USDA Soil Conservation Service [A] 1986) because it is in the frigid soil temperature regime. Also, it has less than 15% fiber (10% rubbed) in the subsurface tier.

PEACHAM TYPICAL PEDON

Classification: coarse-loamy, mixed, nonacid, frigid, Histic Humaquept.
Location: about 10 meters east of route 102, just south of the Pretty Marsh Picnic Area road.
Date described: 9/9/91; JEC.
Physiography: depressional area in a low-lying glacial till landscape.
Parent material: basal till.
Slope: less than 1%.
Relief: smoothly concave.
Drainage: very poorly drained; free water was at 44 cm from the top of the Oi horizon on the date described.
Vegetation: scrub-shrub fen.
Major rooting zone: to 29 cm.
Remarks: description is from field observations.

Oi—0 to 9 cm; dark yellowish brown (10YR 3/4) on broken face and when crushed, peat (fibric material); about 90% sphagnum fiber, about 85% rubbed; massive; very friable; abrupt, wavy boundary.

Oa1—9 to 16 cm; dark reddish brown (5YR 2/2) on broken face and when crushed, muck (sapric material); about 50% fiber, about 15% rubbed; weak fine granular structure; very friable; very strongly acid; abrupt, wavy boundary.

Oa2—16 to 29 cm; dark reddish brown (5YR 2/2) on broken face and when crushed, muck (sapric material); about 10% fiber, about 5% rubbed; moderate very fine granular structure; very friable; 20% cobbles in the lower part; very strongly acid; abrupt, wavy boundary.

A—29 to 40 cm; black (10YR 2/1) and very dark brown (10YR 2/2) gravelly fine sandy loam; strong very fine granular structure; very friable; 30% gravel and cobbles; very strongly acid; abrupt, wavy boundary.

Bg—40 to 45 cm; dark grayish brown (10YR 4/2) gravelly silt loam; many fine distinct dark gray (10YR 4/1) mottles; moderate very fine granular structure; friable; 30% gravel and cobbles; strongly acid; abrupt, wavy boundary.

Cdg—45 to 75+ cm; dark grayish brown (2.5Y 4/2) gravelly fine sandy loam; many coarse distinct grayish brown (2.5Y 5/2) mottles and common medium prominent strong brown (7.5YR 5/8) mottles; massive; firm; 20% gravel and cobbles; moderately acid.

Established series: this pedon fits the range of characteristics for the Peacham established series (USDA Soil Conservation Service [A] 1986) except that it has fibric materials at the surface.

SEARSPORT TYPICAL PEDON

Classification: sandy, mixed, frigid, Histic Humaquept.
Location: 0.2 km north of Route 102 at Town Hill intersection, west of the paved road 0.1 km.
Date described: 9/9/91; JEC.
Physiography: low, flat, poorly defined drainageway.
Parent Material: glaciomarine sands.
Slope: less than 1%.
Microrelief: poorly defined cradle-and-mound.
Drainage: very poorly drained; free water was at 27 cm from the top of the Oi horizon on the date described.
Vegetation: hardwood swamp.
Major rooting zone: to 28 cm.
Remarks: description is from field observations with a bucket auger.

Oi—0 to 4 cm; dark yellowish brown (10YR 4/4) on broken face and when crushed, peat (fibric material); about 90% fiber, about 85% rubbed; very friable; abrupt, wavy boundary.

Oa—4 to 22 cm; very dark brown (10YR 2/2) on broken face and when crushed, muck (sapric material); about 15% fiber, about 10% rubbed; weak very fine granular structure; very friable; very strongly acid; clear, wavy boundary.

A1—22 to 28 cm; very dark brown (10YR 2/2) mucky sandy loam; moderate fine granular structure; very friable; very strongly acid; clear, wavy boundary.

A2—28 to 32 cm; very dark grayish brown (10YR 3/2) mucky sandy loam; weak fine granular structure; very friable; strongly acid; abrupt, smooth boundary.

C1—32 to 40 cm; gray (10YR 5/1) sand; single grain; nonsticky and nonplastic; moderately acid.

C2—40 to 130 cm; dark grayish brown (2.5Y 4/2) sand; single grain; nonsticky and nonplastic; moderately acid.

C3—130 to 155 cm; dark gray (5Y 4/1) loamy sand; single grain; nonsticky and nonplastic; neutral.

Established series: this pedon fits the range of characteristics for the Searsport established series (USDA Soil Conservation Service [A] 1991) except that it has a thin layer of fibric materials at the surface and the reaction is neutral in the lower substratum.

WASKISH TYPICAL PEDON

Classification: dysic, frigid Typic Sphagnofibrist.
Location: about 50 meters north of pond area on the Big Heath.
Date described: 6/25/91; JEC, AJC.
Physiography: raised plateau bog.
Parent Material: sphagnum moss deposits.
Slope: less than 1%.
Microrelief: cradle-and-mound; pedon described in a cradle.
Drainage: very poorly drained; free water was at 19 cm from the top of the Oi1 horizon when described.
Vegetation: scrub-shrub bog.
Remarks: description is from field observations with a bucket auger.

Oi1—0 to 5 cm; dark reddish brown (2.5YR 2/2) on broken face, peat (fibric material) with small pockets of mucky peat (hemic material), dark brown (7.5YR 3/3) when crushed, less than 1% woody fragments; about 90% sphagnum fibers, about 80% rubbed; weak coarse platy structure; very friable; many very fine, fine, and medium, and common coarse roots; extremely acid; abrupt, wavy boundary.

Oi2—5 to 132 cm; reddish gray (5YR 5/2) on broken face, peat (fibric material), dark reddish brown (5YR 3/2) when crushed; about 95% sphagnum fibers, about 90% rubbed, less than 1% coarse woody fragments; massive; nonsticky and nonplastic; common very fine and fine roots, and few medium roots; extremely acid.

Established series: this pedon fits the range of characteristics for the Waskish established series (USDA Soil Conservation Service [A] 1987).

WESTBURY TAXADJUNCT TYPICAL PEDON

Classification: coarse-loamy, mixed, frigid, Typic Epiaquod.
Location: 5 meters east of Pretty Marsh Picnic Area road at first major curve.
Date described: 9/9/91; JEC.
Physiography: depression in a basal till upland.
Parent material: basal till.
Slope: 2%, undulating.
Drainage: poorly drained; free water at 55 cm from the top of the Oa horizon on the date described.
Vegetation: mixed disturbed forested wetland.
Major rooting zone: to 12 cm.
Remarks: description is from field observations.

Oa—0 to 12 cm; black (5YR 2/1) on broken face and when crushed, muck (sapric material); about 5% fiber, less than 5% rubbed; moderate fine and very fine granular structure; very friable; 30% cobbles and gravel; very strongly acid; abrupt, wavy boundary.

A—12 to 25 cm; black (10YR 2/1) and very dark gray (10YR 3/1) very cobbly mucky fine sandy loam; weak fine granular structure; very friable; 35% cobbles and gravel; strongly acid; abrupt, wavy boundary.

Eg—25 to 29 cm; gray (5Y 5/1) gravelly sandy loam; many fine prominent dark yellowish brown (10YR 3/4) mottles; weak fine granular structure; very friable; 30% cobbles and gravel; moderately acid; abrupt, wavy boundary.

Bh—29 to 33 cm; dark brown (7.5YR 3/2) gravelly fine sandy loam; weak fine subangular blocky structure; very friable; moderately acid; abrupt, broken boundary.

Bg—33 to 52 cm; grayish brown (2.5Y 5/2) gravelly fine sandy loam, with pockets of sandy loam; many medium distinct olive gray (5Y 5/2) mottles and many coarse prominent dark yellowish brown (10YR 3/4) mottles; massive; friable; 20% gravel and cobbles; moderately acid; abrupt, wavy boundary.

Cdg—52 to 60+ cm; olive gray (5Y 5/2) gravelly fine sandy loam; many coarse prominent dark yellowish brown (10YR 4/6) mottles and many coarse distinct gray (5Y 6/1) mottles; weak fine and medium platy structure; firm; 20% gravel and cobbles; moderately acid.

Established series: this pedon is outside the range of characteristics for the Westbury established series (USDA Soil Conservation Service [A] 1988) because it is poorly drained rather than somewhat poorly drained and lacks a true fragipan. Also, it lacks a Bs horizon and is mottled in the E horizon rather than in the Bh horizon. The subsoil has a hue of 5Y.

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APPENDIX 2. PLANT SPECIES OBSERVED IN THE ACADIA REGION'S WETLANDS*

IND	Genus—Species—Common Name
FAC	*Abies balsamea* (balsam fir)
FAC	*Acer rubrum* (red maple)
FACU-	*Agropyron repens* (quackgrass)
FACW	*Agrostis alba* (redtop)
NI	*Agrostis gigantea* (black bentgrass)
FACW	*Agrostis stolonifera* (spreading bentgrass)
FAC	*Alnus crispa* (green alder)
FACW+	*Alnus rugosa* (speckled alder)
FAC	*Amelachier* spp. (serviceberry)
OBL	*Andromeda glaucophylla* (bog rosemary)
FACU	*Aralia nudicaulus* (sarsaparilla)
NI	*Arctostaphylos uva-ursi* (bearberry)
OBL	*Arethusa bulbosa* (swamp pink)
FACW-	*Arisaema triphyllum* (Jack-in-the-pulpit)
FAC	*Aronia melanocarpa* (black chokeberry)
FACW-	*Aster lateriflorus* (calico aster)
FACW+	*Aster nemoralis* (bog aster)
FACW+	*Aster novi-belgii* (New York aster)
OBL	*Aster radula* (rough aster)
OBL	*Aster subulatus* (annual saltmarsh aster)
FACW	*Aster umbellatus* (flattop white aster)
FAC	*Athyrium filix-femina* (lady fern)
FACW	*Atriplex patula* (halberd leaf saltbush)
FAC	*Betula alleghaniensis* (yellow birch)
FACU	*Betula papyrifera* (paper birch)
FAC	*Betula populifolia* (gray birch)
FACW+	*Calamagrostis canadensis* (blue-joint reedgrass)
FACW+	*Calopogon tuberosus* (grasspink)
OBL	*Campanula aparinoides* (marsh bellflower)
OBL	*Cardamine pensylvanica* (Pennsylvania bittercress)
OBL	*Carex canescens* (hoary sedge)
OBL	*Carex crinita* (fringed sedge)
OBL	*Carex cryptolepis* (northeastern sedge)
FACW+	*Carex disperma* (soft-leaved sedge)
OBL	*Carex echinata* (little prickly sedge)
OBL	*Carex exilis* (coast sedge)
NI	*Carex folliculata* (long sedge)
OBL	*Carex hormathodes* (marshstraw sedge)
FACW+	*Carex intumescens* (bladder sedge)
OBL	*Carex lacustris* (lakebank sedge)
OBL	*Carex lasiocarpa* (woolly-fruit sedge)
OBL	*Carex lupulina* (hop sedge)
OBL	*Carex lurida* (shallow sedge)
OBL	*Carex oligosperma* (few-seeded sedge)
OBL	*Carex paleacea* (chaffy sedge)
OBL	*Carex paupercula* (poor sedge)
OBL	*Carex rostrata* (beaked sedge)
OBL	*Carex stricta* (tussock sedge)
FAC	*Carex tenera* (slender sedge)
OBL	*Carex trisperma* (three fruited sedge)
OBL	*Carex vesicaria* (inflated sedge)
OBL	*Carex viridula* (little green sedge)
OBL	*Carex vulpinoidea* (fox sedge)
OBL	*Chamaedaphne calyculata* (leatherleaf)
OBL	*Cladium mariscoides* (smooth sawgrass)
	Cladonia alpensis (reindeer moss)
	Cladonia arbuscular
	Cladonia gracilis
FAC	*Clintonia borealis* (blue beadlily)
FACW	*Coptis trifolia* (Alaska goldthread)
FAC-	*Cornus canadensis* (Canada bunchberry)
FACU-	*Corylus cornuta* (beaked hazelnut)
OBL	*Cyperus filicinus* (slender flatsedge)
	Deschamsia flexuosa (slender hairgrass)
OBL	*Drosera intermedia* (spoonleaf sundew)
OBL	*Drosera rotundifolia* (roundleaf sundew)
FAC	*Dryopteris noveboracencis* (New York fern)
FACW+	*Dryopteris thelypteris* (marsh fern)
FAC+	*Dryopteris spinulosa* (spinulose woodfern)
OBL	*Dulichium arundinaceum* (three-way sedge)
OBL	*Eleocharis palustris* (spikerush)
FACW-	*Elymus virginicus* (Virginia wild-rye)
FACW	*Empetrum nigrum* (black crowberry)
OBL	*Epilobium leptophyllum* (narrow willow-herb)
OBL	*Epilobium palustre* (marsh willow-herb)
FACW	*Equisetum palustre* (marsh horsetail)
FACW	*Equisetum sylvaticum* (woodland horsetail)
OBL	*Eriocaulon septangulare* (pipewort)
OBL	*Eriophorum angustifolium* (narrow-leaf cottongrass)
OBL	*Eriphorum spissum* (hare's tail)
OBL	*Eriophorum tenellum* (few-nerve cottongrass)
OBL	*Eriophorum virginicum* (tawny cottongrass)
FACW+	*Eupatorium perfoliatum* (common boneset)
FACW	*Eupatorium maculatum* (spotted Joe Pye weed)
FACU	*Festuca rubra* (red fescue)
FACU	*Fraxinus americana* (white ash)
OBL	*Galium asprellum* (rough bedstraw)
OBL	*Galium palustre* (marsh bedstraw)
FACW	*Gaultheria hispidula* (creeping snowberry)
FACU	*Gaultheria procumbens* (teaberry)
FACU	*Gaylussacia baccata* (black huckleberry)
FAC	*Gaylussacia dumosa* (dwarf huckleberry)
OBL	*Glaux maritima* (sea milkwort)
OBL	*Glyceria borealis* (floating manna grass)
OBL	*Glyceria canadensis* (Canada manna grass)
FACW	*Hierochloe odorata* (holy grass)
FAC	*Hordeum jubatum* (fox-tail barley)
FACW	*Hypericum canadense* (Canadian St. John's-wort)
NI	*Hypericum virginicum* (swamp St. John's-wort)
FACW-	*Ilex glabra* (inkberry)
FACW+	*Ilex verticillata* (common winterberry)
FACW	*Impatiens capensis* (spotted touch-me-not)
OBL	*Iris versicolor* (blueflag)
FACW+	*Juncus balticus* (Baltic rush)
OBL	*Juncus canadenis* (Canada rush)
FACW	*Juncus effusus* (soft rush)
FACW+	*Juncus filiformis* (thread rush)
FACW+	*Juncus gerardii* (black grass)
OBL	*Juncus militaris* (bayonet rush)

Symbology: IND (Indicator status), OBL (Obligate), FACW (Facultative Wetland), FAC (Facultative), FACU (Facultative Upland), NI (no indicator assigned), *(Limited ecological information), + (higher portion of frequency range), and - (lower portion of frequency range). See discussion of hydrophyte definition and concept in Chapter 6.

IND	Genus—Species—Common Name
FACU	*Juniperus communis* (creeping juniper)
FAC	*Kalmia angustifolia* (sheep laurel)
OBL	*Kalmia polifolia* (bog laurel)
FACW	*Larix laricina* (American larch)
OBL	*Ledum groenlandicum* (labrador-tea)
OBL	*Lemna minor* (lesser duckweed)
OBL	*Limonium nashii* (northern sea-lavender)
FACW+	*Listera cordata* (heart-leaf twayblade)
FACW	*Lysimachia ciliata* (fringed loosestrife)
OBL	*Lysimachia terrestris* (swamp loosestrife)
FACW+	*Lythrum salicaria* (purple loosestrife)
FAC-	*Maianthemum canadense* (Canada mayflower
FAC	*Malaxis unifolia* (green adder's mouth)
OBL	*Mimulus ringens* (monkey-flower)
FACU	*Mitchella repens* (partridgeberry)
OBL	*Myrica gale* (sweetgale)
FAC	*Myrica pensylvanica* (northern bayberry)
OBL	*Nemopanthus mucronatus* (mountain holly)
OBL	*Nuphar variegatum* (yellow water lily)
OBL	*Nymphaea odorata* (white water lily)
FACW	*Onoclea sensibilis* (sensitive fern)
FACW	*Osmunda cinnamomea* (cinnamon fern)
FAC	*Osmunda claytoniana* (interrupted fern)
OBL	*Osmunda regalis* (royal fern)
FACW+	*Phalaris arundinacea* (reed canary grass)
FACU	*Picea glauca* (white spruce)
FACW-	*Picea mariana* (black spruce)
FACU	*Picea rubens* (red spruce)
FACU	*Pinus strobus* (eastern white pine)
FACW	*Platanthera psychodes* (small purple fringed orchid)
FACW+	*Platanthera X clavellata* (small green woodland orchid)
OBL	*Pogonia ophioglossoidea* (rose pogonia)
	Polygonum spp. (knotweed)
OBL	*Polygonum sagittatum* (arrow-leaf tearthumb)
	Polystichum strictum (moss)
OBL	*Pontedaria cordata* (pickerel weed)
FACU	*Populus tremuloides* (quaking aspen)
OBL	*Potamogeton natans* (floating-leaf pondweed)
OBL	*Potentilla anserina* (silverweed)
FACU	*Prunus serotina* (black cherry)
FACU	*Pteridium aquilinum* (bracken fern)
FACU-	*Quercus rubra* (northern red oak)
OBL	*Ranunculus cymbalaria* (seaside buttercup)
OBL	*Ranunculus pensylvanicus* (Pennsylvania buttercup)
FACW	*Rhododendron canadense* (rhodora)
OBL	*Rhynchospora alba* (white beakrush)
	Ribes spp. (wild black currant)
FACW+	*Rosa nitida* (shining rose)
FACU-	*Rubus allegheniensis* (Allegheny blackberry)
FACU	*Rubus chamaemorus* (cloudberry)
FAC-	*Rubus hispidus* (bristly blackberry)
FACU	*Rumex crispus* (dooryard dock)
OBL	*Ruppia maritima* (widgeon grass)
OBL	*Sagittaria latifolia* (broadleaf arrowhead)
OBL	*Salicornia europaea* (slender glasswort)
	Salix spp. (white willow)
OBL	*Sarracenia purpurea* (northern pitcher-plant)
OBL	*Scheuchzeria palustris* (podgrass)
OBL	*Scirpus acutus* (hard-stem bulrush)
FACW+	*Scirpus pungens* (Olney's bulrush)
OBL	*Scirpus cespitosus* (tufted bulrush)
FACW+	*Scirpus cyperinus* (woolgrass)
OBL	*Scirpus maritimus* (saltmarsh bulrush)
FACU-	*Scirpus validus* (soft-stem bulrush)
NI	*Scutellaria epilobiifolia* (marsh skullcap)
OBL	*Sium suave* (water parsnip)
OBL	*Smilacina trifolia* (false Solomon's seal)
FAC	*Smilax herbacea* (smooth carrion-flower)
FACU	*Solidago canadenis* (Canada goldenrod)
FACW	*Solidago graminifolia* (grass-leaved goldenrod)
FACW	*Solidago sempervirens* (seaside goldenrod
OBL	*Solidago uliginosa* (bog goldenrod)
OBL	*Sparganium eurycarpum* (giant burreed)
OBL	*Spartina alterniflora* (saltmarsh cordgrass)
OBL	*Spartina patens* (saltmeadow cordgrass)
OBL	*Spartina pectinata* (prairie cordgrass)
	Sphagnum cuspidatum (sphagnum moss)
	Sphagnum flavicomans
	Sphagnum fuscum
	Sphagnum pulchrum
	Sphagnum rubellum
FAC+	*Spiraea latifolia* (meadowsweet)
FACW	*Spiraea tomentosa* (steeplebush)
OBL	*Suaeda linearis* (annual sea blite)
OBL	*Suaeda maritima* (white sea blite)
OBL	*Symplocarpus foetidus* (skunk cabbage)
FACW+	*Thalictrum polyganum* (meadow rue)
FAC	*Thalictrum dioicum* (early meadow rue)
FACW	*Thuja occidentalis* (northern white cedar)
FAC	*Toxicodendron radicans* (poison ivy)
FAC	*Trientalis borealis* (American starflower)
OBL	*Triglochin maritimum* (seaside arrowgrass)
FACU	*Tsuga canadensis* (eastern hemlock)
OBL	*Typha angustifolia* (narrowleaf cattail)
OBL	*Typha latifolia* (broadleaf cattail)
OBL	*Utricularia cornuta* (horned bladderwort)
OBL	*Utricularia intermedia* (flatleaf bladderwort)
OBL	*Utricularia purpurea* (purple bladderwort)
	Utricularia vulgaris (common bladderwort)
FACU-	*Vaccinium angustifolium* (lowbush blueberry)
FACW-	*Vaccinium corymbosum* (highbush blueberry)
OBL	*Vaccinium macrocarpon* (large cranberry)
FAC	*Vaccinium myrtilloides* (velvet leaf blueberry)
OBL	*Vaccinium oxycoccos* (small cranberry)
FACW+	*Veratrum viride* (false-hellebore)
FACW+	*Verbena hastata* (blue vervain)
FACW	*Viburnum cassinoides* (withe-rod)
FACW-	*Viburnum recognitum* (northern arrowwood)
FACW+	*Xyris caroliniana* (Carolina yellow-eyed-grass)
OBL	*Zizania aquatica* (wildrice)
OBL	*Zostera marina* (eelgrass)

Symbology: OBL (Obligate), FACW (Facultative Wetland), FAC (Facultative), FACU (Facultative Upland), NI (no indicator assigned), *(Limited ecological information), +(higher portion of frequency range), and - (lower portion of frequency range). See discussion of hydrophyte definition and concept in Chapter 6.

APPENDIX 3. SIGNIFICANT LAKES AND PONDS OF ACADIA NATIONAL PARK[7]

AUNT BETTY'S POND

Township: Bar Harbor
Size: 34 acres
County: Hancock
USGS Quad: Seal Harbor, ME
Basin: Coastal

Summary of Significance
Aunt Betty's Pond is located in Acadia National Park. It has outstanding scenic resources, a significant brook trout, golden shiner and common sucker fishery and one state threatened rare plant station.

General Description
This is an eutrophic pond with an average depth of 3 feet and a maximum depth of 7 feet.

Description of Significant Resources Features

Fisheries: This is a low quality, shallow, marshy pond. The water is too warm to support many trout. Major species include brook trout, golden shiner, nine-spine stickleback, and common sucker. The outlet, Richardson Brook, supports most of the brook trout population.

Wildlife: No known significant wildlife features.

Scenic: This pond has a number of outstanding scenic features; a high complexity of surrounding relief, an island, and an undeveloped forested shoreline.

Shore Character: No significant features reported.

Botanic: Small purple bladderwort, *Utricularia resupinata*, is a state significant species.

Cultural: No significant features reported.

Geologic: No significant features reported.

Hydrologic: No significant features reported.

BUBBLE POND

Township: Bar Harbor
Size: 32 acres
County: Hancock
USGS Quad: Seal Harbor
Basin: Coastal

Summary of Significance
Bubble Pond has outstanding cultural and scenic features, and significant botanic, physical, shoreline, and fishery features. This spectacular, relatively pristine pond is located in Acadia National Park.

General Description
This is a coldwater, mesotrophic pond with an average depth of 21 feet and a maximum depth of 39 feet. There is no direct vehicle access, although the Park Loop Road is adjacent to the northern edge of the pond. A hiking trail runs along the western edge of the pond.

Description of Significant Resources Features

Fisheries: Brook trout, which are the principal fishery, are stocked by the state. They are the only gamefish in the pond.

Scenic: Cliffs, rockslides, a bouldered shore, and high dramatic relief contribute to this pond's outstanding scenery. This pond is surrounded by abrupt mountain ridges that dramatically rise from the edge of the pond.

Shore Character: Bubble Pond has significant shore character features which consist of a small pocket beach and a rocky shore. Ninety% of the shoreline is forested.

Botanic: *Subularia aquatica*, awlwort, is a significant botanical feature from this pond. This species was given the status of Special Concern by the State Planning Office's Endangered Plant Technical Advisory Committee.

Geologic: No significant features reported.

Hydrologic: No significant features reported.

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[7] Taken from Parkin, D. J. Lortie, R. Humphrey, and F. DiBello. 1989. Maine's finest lakes: The results of the Maine lakes study. A report prepared for the Maine Critical Areas Program. Planning Report No. 90. 221p.

EAGLE LAKE

Township: Bar Harbor
Size: 436 acres
County: Hancock
USGS Quad: Seal Harbor, Southwest Harbor, ME
Basin: Coastal

Summary of Significance
Eagle Lake has outstanding physical, cultural, and scenic features, and significant botanic and fishery features. In addition, this lake is located adjacent to Sommes Sound, and is part of Acadia National Park.

General Description
Eagle Lake is an oligotrophic, coldwater lake with an average depth of 44 feet and a maximum depth of 110 feet. Route 102 runs along the eastern shore of the lake. One boat launch exists along the eastern shore.

Description of Significant Resources Features

Fisheries: The principal fisheries are for landlocked salmon, brook trout and togue, which are all stocked. The lake also supports rainbow smelt.

Scenic: The outstanding scenery on this pond is due to high dramatic relief, 3 islands, and a bouldered shore.

Shore Character: No significant features reported.

Botanic: *Subularia aquatica*, awlwort, is a significant botanical feature of this pond. This species was given the status of Special Concern by the State Planning Office.

Cultural: The Carriage Path System is an outstanding cultural feature of this pond.

Geologic: This pond has significant cliffs, and outstanding rock outcrops.

Hydrologic: No significant features reported.

ECHO LAKE

Township: Bar Harbor
Size: 237 acres
County: Hancock
USGS Quad: Southwest Harbor, ME
Basin: Coastal

Summary of Significance
Echo Lake is located in Acadia National Park. This lake has outstanding scenic and shoreline features, as well as significant botanic, physical, and fish resources. This rich assemblage of unique natural resource features is uncommon in the organized townships.

General Description
This is an shallow, coldwater, oligotrophic lake with an average depth of 28 feet and a maximum depth of 66 feet. A water control structure at the northern end of the lake regulates water levels. Acadia, St. Sauvuer, and Beech Mountains surround this lake, creating a scenically pleasing landscape. This lake is within the boundaries of Acadia National Park.

Description of Significant Resources Features

Fisheries: Landlocked salmon and brook trout are the significant principal fisheries. The lake was stocked with Sunapee trout in 1974, however this practice was discontinued. Echo Lake has been reclaimed once, in 1956.

Scenic: High dramatic relief, a beach at south end, rockslides, and a partially bouldered shore make the scenic quality of this lake outstanding. The surrounding mountains picturesquely frame this oceanside lake.

Shore Character: Despite some development at the south end, 80% of the shore is forested. Ten percent of the shore is beach, and 10% is bouldered. The broad beach, protruding bedrock ledge, and rocky shore all contribute to its outstanding shoreline character.

Botanic: *Aresthusa bulbosa*, a proposed state watch list plant species, occurs in the shoreland zone around Echo Lake.

Cultural: A historic carriage path skirts the lake.

Geologic: Echo Lake contains a significant cliff along its southeastern shoreline.

Hydrologic: No significant features reported.

JORDAN POND

Township: Mount Desert
Size: 187 acres
County: Hancock
USGS Quad: Acadia National Park
Basin: Presumpscot

Summary of Significance
Jordan Pond has outstanding scenic features and significant botanic, physical, cultural, shoreline, and fishery features. This rich assemblage of natural resource features is uncommon in the organized townships. The pond is nestled in between The Bubbles, Pemetic Mountain, The Triad, Penobscot Mountain, and Jordan Ridge, and occurs completely within Acadia National Park.

General Description
This is an oligotrophic coldwater pond. Average depth is 84 feet and maximum depth 150 feet. A water control structure exists along the pond's southern outlet. Also located at the southern end of the pond is a boat launch. Jordan Pond is located within Acadia National Park, which receives a large amount of visitor use.

Description of Significant Resources Features

Fisheries: The principal fishery species, landlocked salmon and togue are both stocked and provide a significant fishery resource. The lake also supports rainbow smelt and brook trout.

Wildlife: Not rated, possess moderate value upland habitat for sensitive species.

Scenic: The high dramatic relief, cliffs, extremely clear water, and bouldered shore contribute to the outstanding scenic quality of this pond.
Despite being partly developed, it is still very scenic.

Shore Character: Jordan Pond has a small narrow beach along its predominantly rocky shore. The shoreline is approximately 80% forested, marsh makes up 10% of the shoreline. There is a National Park Service facility at the south end.

Botanic: The shoreland zone of this pond includes *Cypripedium reginae*, Showy Lady's Slipper, a plant species proposed to be listed as threatened in Maine.

Cultural: The Carriage Path System is a historical feature present around Jordan Pond.

Geologic: High cliffs are significant geologic features on this pond.

Hydrologic: No significant features reported.