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MAINE'S COASTAL WETLANDS:

I. TYPES, DISTRIBUTION, RANKINGS, FUNCTIONS AND VALUES

by

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SUMMARY

This two volume report addresses the need for reference material on coastal wetlands of Maine and the need for a standard wetland assessment method for intertidal wetlands used in the permitting process statewide.

Volume I, designed for reference by DEP project managers, review agencies and consultants, provides biological and geological information on Maine's coastal habitats (wetlands) and summarizes current development over the past five years within coastal wetlands in Maine. Detailed information on the types, acreage, and distribution of seven intertidal habitats is provided. Functions, values and management suggestions to reduce wetland damage and loss are furnished for seven intertidal habitats, three subtidal habitats and three vegetated habitats. Each summary contains a table of functions and values for quick reference. Intertidal habitats are ranked according to their productivity and sensitivity to development. A short summary on seasonal variability in marine environments is provided to assist in the review of biological data.

Volume II, written for professional consultants, provides recommended functional assessment guidelines that can satisfy the functional wetland assessment requirement in intertidal habitats for Natural Resources Protection Act (NRPA) applications. It includes suggested sampling approaches by permitted activity type and their associated impacts. The guidelines include both qualitative and quantitative protocols for intertidal habitats.

INTRODUCTION

Introduction

Anyone, who has flown, driven or sailed the entire coast of Maine, knows the incredible diversity of coastal environments along the coastline of Maine. Long stretches of sand beaches, expansive salt marshes, irregular rocky ledges, and vast mud flats are a few of the environments distributed along the approximately 5,300 miles of shoreline between Kittery and Calais.

Maine's coastal wetlands are one of the most important environments to the people of Maine. In fact, 540,000 people or 43 % of the population of Maine live in the 144 coastal towns of Maine that comprise only 12 % of the area of the state (Maine State Planning Office 1997). They are used by residents and non-residents for numerous recreational activities from fishing to sea kayaking. They support a multi-million dollar commercial and recreational lobster, clam and fishing industry. Coastal wetlands are the main attraction to outsiders and have become the single most important resource for the tourism and recreation industry in Maine (Colgan and Plumstead 1995).

Over the past several years commercial and private development pressures within the coastal wetlands of Maine have increased. Out of state residents, attracted by the natural beauty of Maine and affordable waterfront real estate (as compared to other New England states), purchase shorefront property and construct waterfront summer homes, piers, and docks. In addition, over eight million tourists and summer residents visit Maine annually with a majority of the people visiting coastal communities (Maine State Planning Office 1997).

As people relocate to and visit the desirable coastal communities, demands on the natural environment are inevitable. New structures built to accommodate increasing numbers of tourists and residents alter water quality, displace and/or shade habitats, increase disturbance, erosion and stormwater runoff and change circulation patterns. Coastal areas are continually threatened by increased commercial and private developments that alter, fill, dredge, impound, armor and shade marine environments.

As a result of population growth along the coast, applications for alterations and development are received daily by the DEP. Each project is reviewed for adverse impacts to the coastal wetland. The quality of information provided in the application determines the ease and speed of review and directly affects the outcome of the project.

Maintaining a balance between development and preservation is crucial to preserving the Maine lifestyle and promoting a prosperous economy. State environmental laws have been developed to reduce impacts to marine habitats while allowing growth and development.

Legal Basis for Protection

To protect the natural environment from adverse impact associated with development, the Natural Resources Protection Act (NRPA) (38 MRSA 480-A to 480-Z) including the Wetland Protection Rules (Chapter 310), and the Water Classification Act (38 MRSA, Section 465-B) were developed between 1988-1994 to prevent pollution, degradation, alteration, and habitat loss in tidal wetlands. Under these rules and statutes, the Maine Department of Environmental Protection (MDEP) is bound to restrict activities that will "unreasonably harm any significant wildlife habitat............estuarine or marine fisheries or other aquatic life" (38 MRSA 480-D) or cause a net loss in the functions and values of coastal wetlands.

> **Coastal Wetlands:** All tidal and sub-tidal areas, including all areas below any identifiable debris line left by tidal action; all areas with vegetation present that is tolerant of saltwater and occurs primarily in a salt water or estuarine habitat; and any swamps, marsh, bog, beach, flat, or other contiguous lowland which is subject to tidal action during the maximum spring tide level as identified in tide tables published by the National Ocean Service (38 MRSA 480-B).

Since the inception of the Natural Resources Protection Act in 1988, any person seeking to develop a site, repair a permanent structure or physically alter soils in, on or over a coastal wetland or within 100 feet of the coastline must first receive approval from the DEP. The applicant may file an individual NRPA permit or a Permit-by Rule (PBR) permit. Individual NRPA permits may require state and federal agency review and approval, mapping, site and project description, functional wetland assessment, alternatives analysis, and compensation plan. Permit-by Rule activities are routine activities that should not cause significant harm to the marine environment provided that the standards are followed and, therefore, do not require thorough departmental evaluation, wetland functional assessments or inter-agency review. Applicants simply file a one page DEP Permit-by-Rule notification form with a site location map and photographs of the existing conditions of the site. The application is reviewed by DEP staff and if the applicant meets Permit-by-Rule standards than the project can commence 14 days from the date of submission without additional notification or site visit by DEP personnel.

Larger projects that alter greater than 500 sq ft of coastal wetlands and, therefore, do not meet the PBR standards require wetland assessments from consultants hired by the applicant and project review comments from as many as seven different organizations. Assessments identify the functions and values of the wetland, estimate the impact and describe how to minimize the impact. Review comments are received by DEP from Maine Department of Marine Resources (DMR), Maine Department of Inland Fisheries and Wildlife (IF&W), Army Corp of Engineers (ACOE), the Maine Geological Survey (MGS) and Department of Conservation Submerged Lands. Additional comments from

National Marine Fisheries Service (NMFS), the US Fish and Wildlife Service (USF&WS), and the Environmental Protection Agency (EPA) are received and examined by the Army Corps of Engineers. Federal and state agency comments target commercial fisheries concerns, rare plant habitat, significant wildlife habitat, navigational conflicts, geological processes and other issues that may be affected by the proposed development and/or modification. All comments and functional assessments are reviewed and evaluated by DEP project managers before the decision is made to either grant or deny the permit.

Even though Maine has well intended environmental laws for the management of coastal wetlands, there are gaps in the review process that the laws don't address. First, there is no standard functional wetland assessment methodology for consultants to follow. DEP instead receives a variety of professional wetland functional and impact assessments. Assessments vary from site to site, region to region, and consultant to consultant. Due to the extreme variation in composition and content of the assessments, there is a need for standardization of the assessment method so all projects are evaluated with equal thoroughness statewide. Secondly, information on Maine's coastal wetland functions and values is not readily accessible to DEP project managers, enforcement staff, developers, consultants, and review agencies.

Report Objective

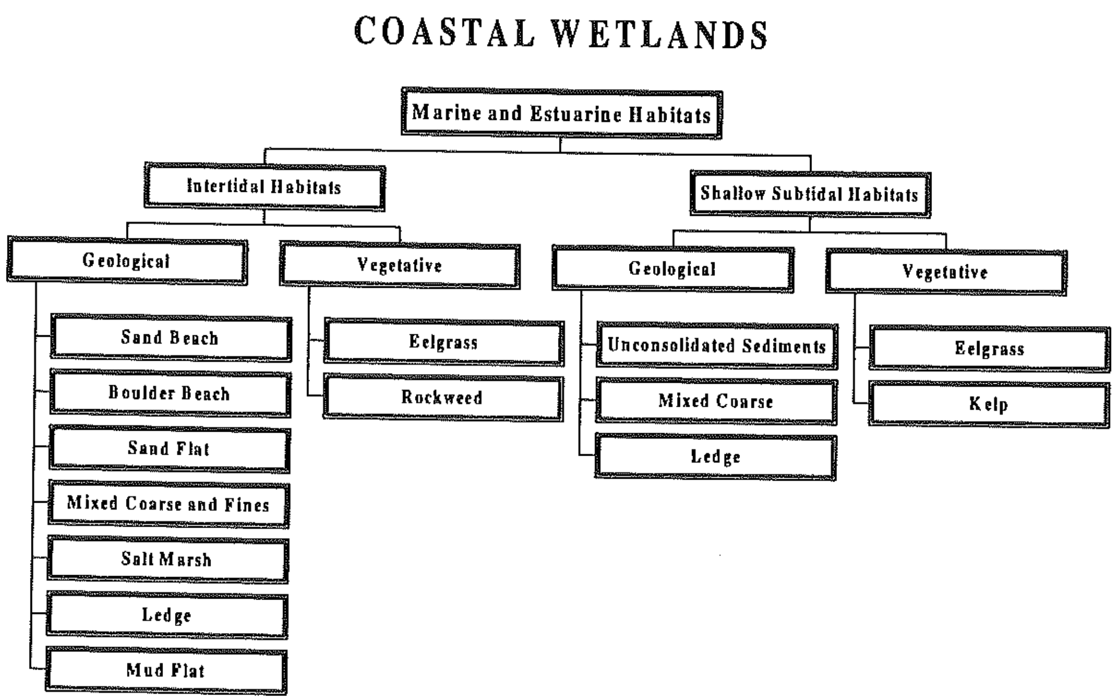
This two-volume document was developed, with the help of many biologists and geologists inside and outside the department, to improve standardization of the permit process, help to educate staff on coastal wetlands in Maine, and improve habitat protection. It is intended to help applicants submit projects in a manner consistent with the law as well as facilitate review by DEP and other state agencies. It should help standardize the assessment process across all DEP regions and reduce confusion for applicants, consultants and staff. It offers information on a variety of different types of marine habitats to enhance protection of all components of coastal ecosystems. New employees unfamiliar with the functions and values of different coastal habitats and assessment methods may find this a useful reference guide. In addition, as these new guidelines are used by consultants, the detailed summaries, maps and photographs may assist reviewers or eliminate the need for DMR regional biologists and DEP staff to conduct as many field visits to make recommendations and decisions.

Volume I of this report, the educational component, was developed specifically for DEP permitting staff, but may also interest environmental consultants, state and federal review agencies as well as anyone interested in Maine's coastal environments. Volume II, which outlines the guidelines for functional assessment of intertidal coastal wetlands, was developed specifically for professional environmental consultants with a strong background in marine biology and taxonomy.

Classification of Marine Habitats

The classification of the habitat types within this report are based on the Classification System of Marine and Estuarine Habitats in Maine (Brown 1993) and the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin 1979). For simplification, only seven intertidal habitats, three subtidal habitats and three vegetated habitats are the focus of this report (see Figure 1 and Definitions). Acreage for the intertidal habitats was obtained from the digitized Coastal Marine Geologic Environment Maps (CMGE) created by Barry Timson in 1976 (see Appendix B for a discussion on the data analysis).

Figure 1.



DEFINITIONS

Marine: any seawater having a high salinity (~30 ppt or higher) that is not appreciably diluted by freshwater.
Estuarine: any seawater diluted with freshwater that has a salinity ranging between 0.5 ppt - 30 ppt.
Intertidal: area of coastal wetland between the high water line and the low water line that is exposed to the atmosphere at any time of the year.
Subtidal: area seaward of the lowest extent of the intertidal zone.

Intertidal Marine and Estuarine Habitats

Sand Beach: exposed environments containing at least 75 % sand.
Boulder Beach: exposed environments dominated by boulders.
Sand Flat: protected and semi-protected environments dominated by sandy sediment.
Mixed Coarse and Fines: semi-protected flats consisting of a mixture of rocks, boulders, gravel, sand, cobbles, and mud.
Salt Marsh: persistent nearshore emergent grass habitats.
Ledge: stable bedrock in protected and unprotected locations.
Mud Flat: protected environments containing at least 75 % mud.
Eelgrass: an annual and perennial vascular flowering plant located in low intertidal and shallow subtidal fine sediment marine and estuarine environments.
Rockweed: brown macro-algae (e.g. *Fucus* spp. and *Ascophyullum* spp.) that attach to intertidal hard substrates.

Shallow Marine and Estuarine Subtidal Habitats

Unconsolidated Sediments: submerged environments composed of fine clays, silt, mud, sand, gravel and organic matter.
Mixed Coarse: shallow submerged habitats comprised of larger rocks such as cobble and boulder.
Ledge: submerged stable bedrock in protected and unprotected locations.
Kelp: brown macro-algae (e.g. *Laminaria* spp., *Alaria* spp.) that attach to low intertidal and shallow subtidal hard substrates.

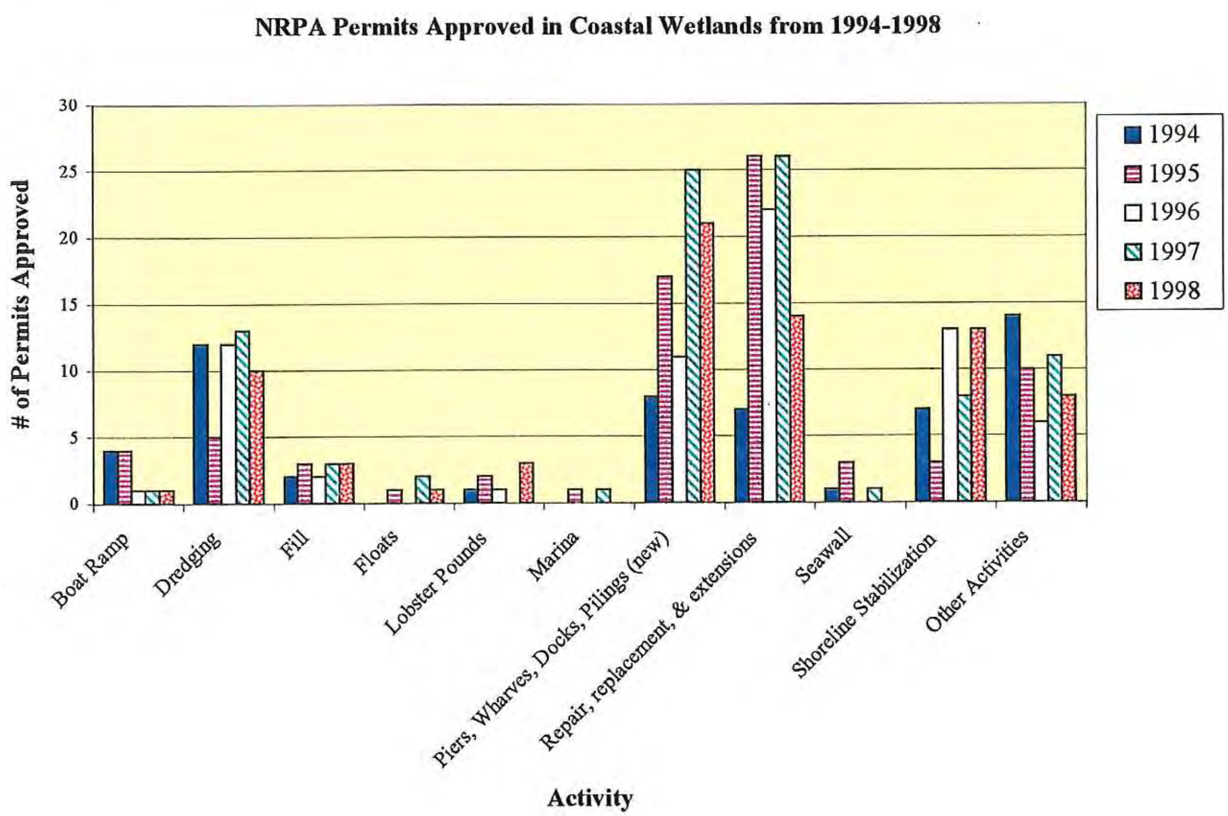
Citations: Classification System of Marine and Estuarine Habitats in Maine (Brown 1993).
Ecology and Management of Maine's Eelgrass, Rockweed and Kelps (Wippelhauser 1996)

COASTAL DEVELOPMENT

NRPA Permitted Activity in Coastal Wetlands

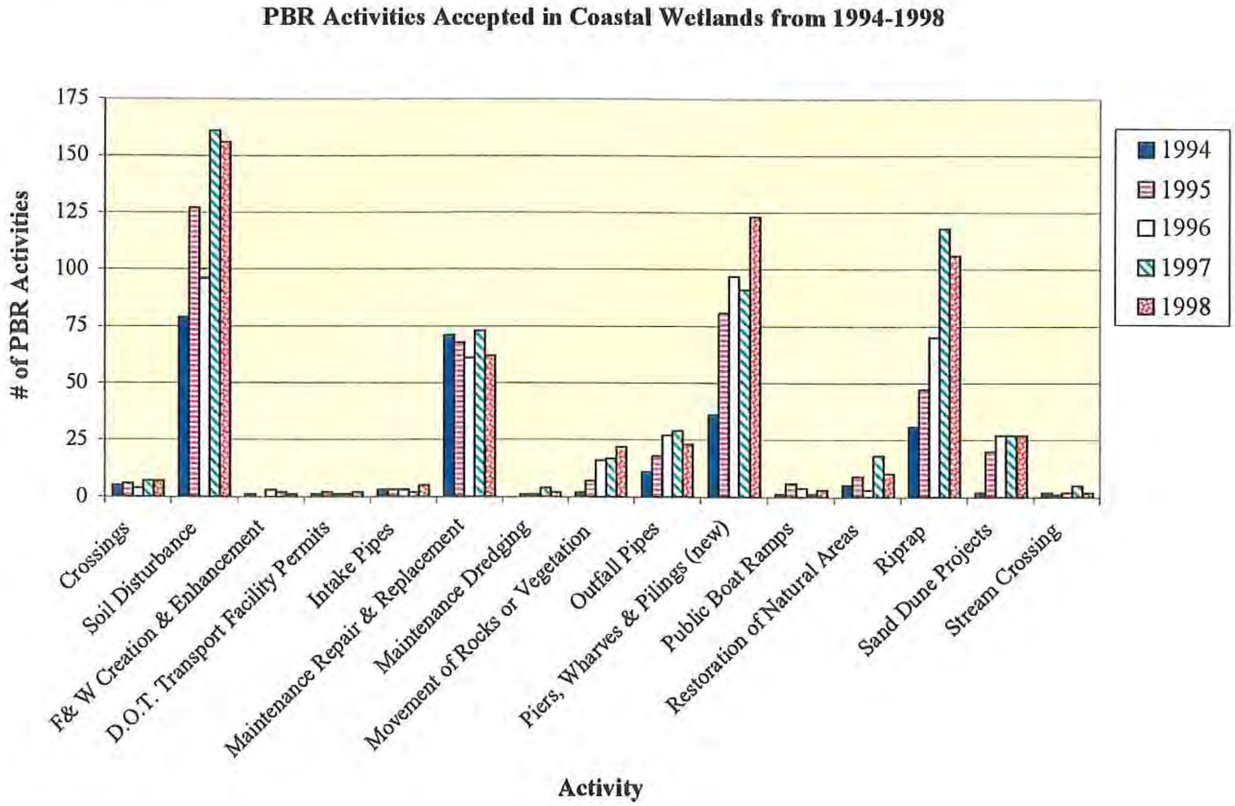
Between the years 1994-1998, 364 individual Natural Resources Protection Act (NRPA) permits were approved within the coastal zone of Maine (Figure 2). In addition to full NRPA permits, 2,168 NRPA Permit-by-Rule (PBR) activities (one Permit-by-Rule permit may have multiple activities) were authorized by DEP since 1994 (Figure 3, see Appendix A for definitions of Permit-by-Rule activities). In the last five years, some activities requiring a full NRPA permit have increased (e.g. piers, shoreline stabilization) while other activities remain about the same (e.g. dredging and fill) (Figure 2).

Figure 2.



Permit-by-Rule activities have increased in almost every category especially soil disturbance, riprap, and new piers, wharves, and pilings (Figure 3). There were 156 Permit-by-Rule permits accepted for soil disturbance and 123 permits accepted for new piers, wharves and pilings in 1998 compared to only 79 for soil disturbance and 36 for piers, wharves and pilings in 1994.

Figure 3.



Five hundred and ten new piers, wharves, and pilings have been approved since 1994. Out of the total, only 82 received full permit review by DEP staff and the rest were permitted under the rapid Permit-by-Rule process. Less than 16 % of the applications for piers required functional wetland assessment and interagency review. In addition, since 1994, as many as 335 of the old piers, docks and other structures in coastal wetlands have undergone repairs, replacement or extensions.

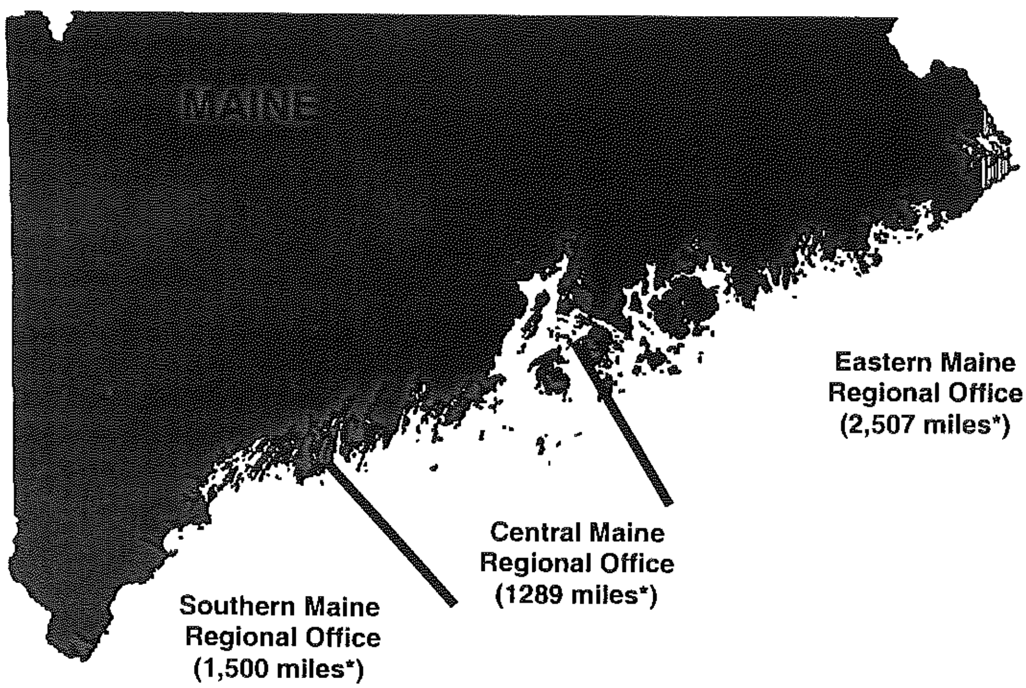
A total of 416 projects to stabilize the shoreline from erosion were licensed since 1994 but only 44 received full NRPA permit review. In other words, only 10 % of shoreline stabilization projects were required to have functional wetland assessments, impact assessments, and alternative analysis.

In summary, coastal development is on the rise and most of the activity statewide is permitted through the Permit-by-Rule process, a process that receives less review and oversight by all regulatory agencies. Since PBR seems to be the fastest growing form of applications, we hope that this Guide will better enable DEP managers and field staff to understand the cumulative impacts caused by PBR activities, consider the implications of amendment to PBR, be on the look out for legal PBR activities that may be causing unintended adverse harm, and equip staff with the basis for educating PBR customers on why certain restrictions exist.

NRPA Permitted Activity in Coastal Wetlands by Regional Office

In order to understand how development and workload differ throughout the coast of Maine, the approved NRPA permitted activities and accepted Permit-by-Rule activities were separated by DEP Region (Figure 4). An analysis of the total number of accepted permits between 1994 - 1998 by regional office confirms that development is on the rise in each coastal region of Maine (Figure 5).

Figure 4.



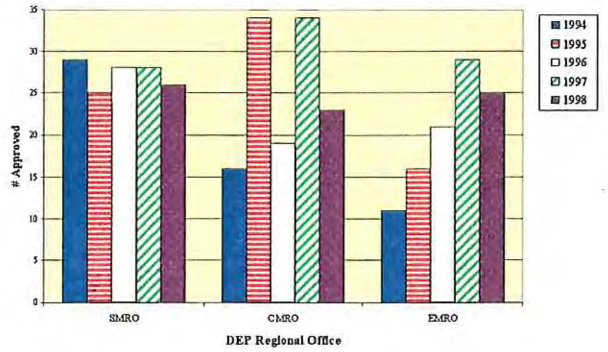
*Shoreline measurements of each region were estimated from 1:24,000 base maps provided by the ME Office of Geographic Information Services (OGIS).

Southern Maine Region

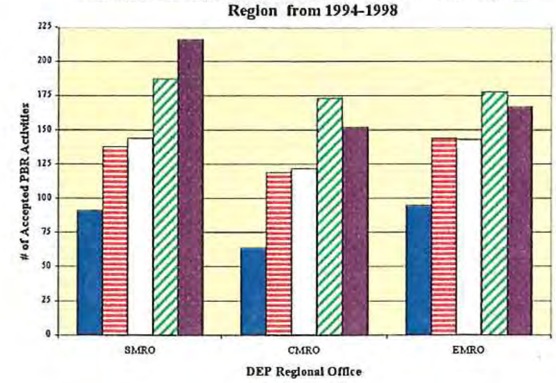
The Southern Maine Region, extending from Kittery to Georgetown, granted 912 permits between 1994 and 1998 amounting to the highest number of permitted activities coastwide. Southern Maine Region Office (SMRO) findings show a steady number of full NRPA permits over the past five years and a dramatic rise in Permit-by-Rule activity

Figure 5.

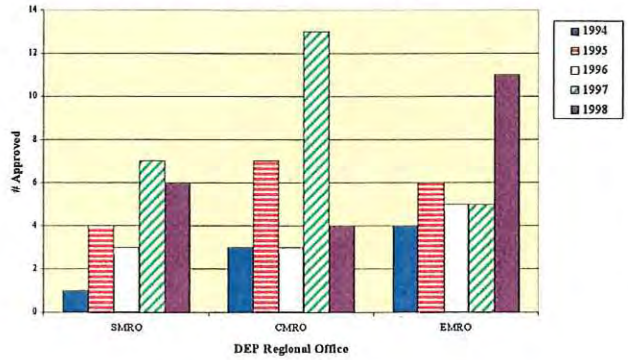
Number of NRPA Permits Approved in Coastal Wetlands by DEP Region from 1994-1998



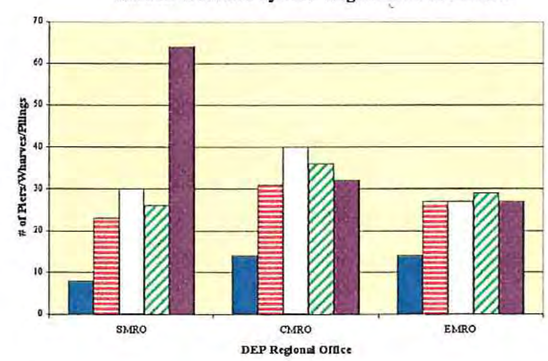
Number of Accepted PBR Permits in Coastal Wetlands by DEP Region from 1994-1998



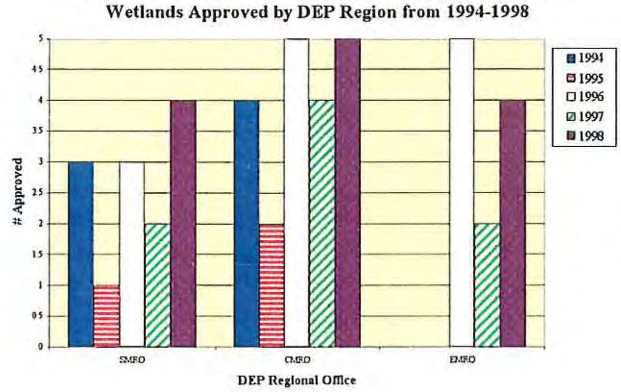
Number of NRPA Permits for Piers, Wharves, Pilings & Docks in Coastal Wetlands Approved by DEP Region from 1994-1998



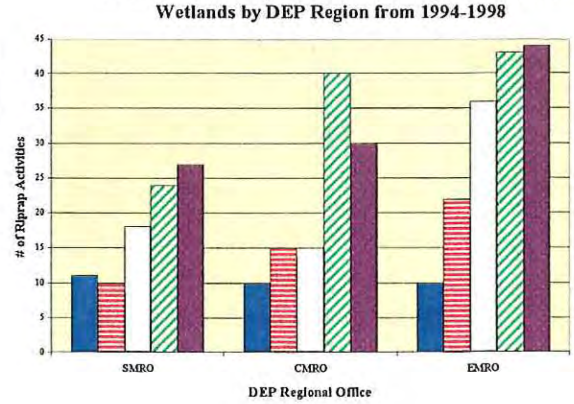
Number of PBR Piers, Wharves, & Pilings Accepted in Coastal Wetlands by DEP Region from 1994-1998



Number of NRPA Permits for Riprap Activities in Coastal Wetlands Approved by DEP Region from 1994-1998



Number of PBR Riprap Activities Accepted in Coastal Wetlands by DEP Region from 1994-1998



(Figure 5). SMRO granted 25 to 29 full NRPA permits in the coastal zone between 1994 and 1998. Permit-by-Rule activity rose from 91 to 216 permits granted during the same time period.

The amount of piers, wharves, and pilings and riprap activities clearly show a rise in activity in southern Maine even in full NRPA permits (Figure 5). A total of six full permits and 64 Permit-by-Rule permits were granted in 1998. This is approximately a 20% increase in pier activity. Riprap activities were more variable but also show a dramatic increase. A total of 31 permits, most through the Permit-by-Rule process, were granted in 1998 compared to only 14 in 1994.

Central Maine Region

The Central Maine Regional Office (CMRO), covering the shortest region in the state (1,289 miles) from Wiscasset to Vinalhaven, granted a smaller total number of NRPA permits and PBR permits between 1994 and 1998 than the Southern Maine Regional Office but a higher number of full permits for two years (Figure 5). Thirty-four full permits were granted in 1995 and 1997 compared to only 16 in 1994. As in southern Maine, central Maine had a rise in Permit-by-Rule activity ranging from 66 to 173 accepted applications.

The Central Maine Region had the highest total PBR activity for piers, wharves and pilings and the second highest riprap activity throughout the regions between 1994 and 1998 (Figure 5). One hundred and eighty three permits were approved for pier, wharves and pilings since 1994 with 30 requiring full NRPA review. Riprapping increased dramatically since 1994, often doubling or nearly tripling the previous years numbers of accepted activity.

Eastern Maine Region

Between 1994 and 1998, the Eastern Maine Regional Office had the second highest number of Permit-by-Rule activities coastwide, the lowest number of full NRPA permits accepted, and a steady continual increase in approved applications (Figures 5). The Eastern Region covers the greatest distance of coastline in the state (2,507 miles) from Isle of Haut to Calais and is the least populated coastal region. The levels of accepted activity along the northeast coast of Maine are now almost comparable to the numbers in the Southern Region, a smaller but more populated area of the state. Seven hundred and thirty-one Permit-by-Rule applications and 102 NRPA applications were approved over the recent five-year period. Over 40 % more applications were received and approved in the Eastern Region in 1998 than in 1994.

Between 1994 and 1998, coastwide, the Eastern Maine Region had the highest number of full NRPA permits approved for piers, wharves and pilings and the highest number of riprapping accepted through the Permit-by-Rule process (Figures 5). Four times as many PBR permits for riprapping were accepted in 1997 and 1998 than in 1994.

Coastal Wetland Impact

Virtually all permitted activities statewide have some type of environmental impact, some more serious than others. In implementing the law, we attempt to identify and distinguish activities causing "unreasonable harm" and "net loss in functions and values".

The following is a list of different types of impacts and examples of each impact that should be considered during review of any proposed project.

Direct Impacts

A direct impact is an impact that will affect or alter a well defined area of wetland. Direct impacts are the "footprint" of the activity. Direct impacts can be caused by filling, dredging, dragging, riprapping, damming, covering, impounding, scraping or other physical activities.

Indirect Impacts

An indirect impact is caused by an activity that alters the surrounding area through associated use or change caused by a direct activity. This impact is in addition to the direct impact and should be considered in the application review process.

Indirect impacts can affect water quality, movement of water and sediment and surrounding environments. Boating activity around wharves and marinas may cause permanent indirect impacts at the site by scouring eelgrass and algal communities, shading plants, polluting waters, and increasing erosion by the creation of wakes. The use of CCA pressure treated lumber has the potential to alter animal communities within a one meter radius of the placement of the treated wood (Lee Doggett, personnel comm.). The placement of a seawall can change wave direction, wave energy and the movement of sediment causing further erosion at the base of the seawall and erosion farther along the shore (Kelley et al. 1989). The placement of dams, causeways or culverts can cause indirect impacts by flooding or restricting water flows to adjacent areas. Riprapping an unstable bluff may slow erosion but may also cutoff sources of mud and sand required to nourish and maintain healthy mud flats and beaches (Kelley et al. 1989).

Temporary Impacts

Temporary impacts are impacts that conceivably last less than a few years. Many activities such as small dredging projects or placement of cable lines may have temporary impacts. Activities with temporary impacts do not change sediment type and the animal communities are likely to be restored to pre-disturbance levels within months to a few years.

Long Term Impacts

Long-term impacts cause a permanent change in the coastal wetland. Permanent changes can be caused by filling or removing habitat, changing habitat type, altering circulation patterns by the placement of large structures, causing chronic erosion, increasing stormwater run-off or toxic contamination, increasing disturbance from humans and pets, and other everlasting alterations in the natural environment.

Positive Impacts

Not all projects have to result in negative impacts. Some activities that restore the natural environment can have positive results. Removal of sawdust accumulations, toxic sediments, invasive species or old rotting structures restores habitats to preexisting conditions. Stabilizing streams by adding vegetative buffers can enhance and restore aquatic life. Restoring tidal flows to ditched salt marshes reestablishes native plant and insect populations returning critical habitats to endangered species and waterfowl.

Multiple Impacts

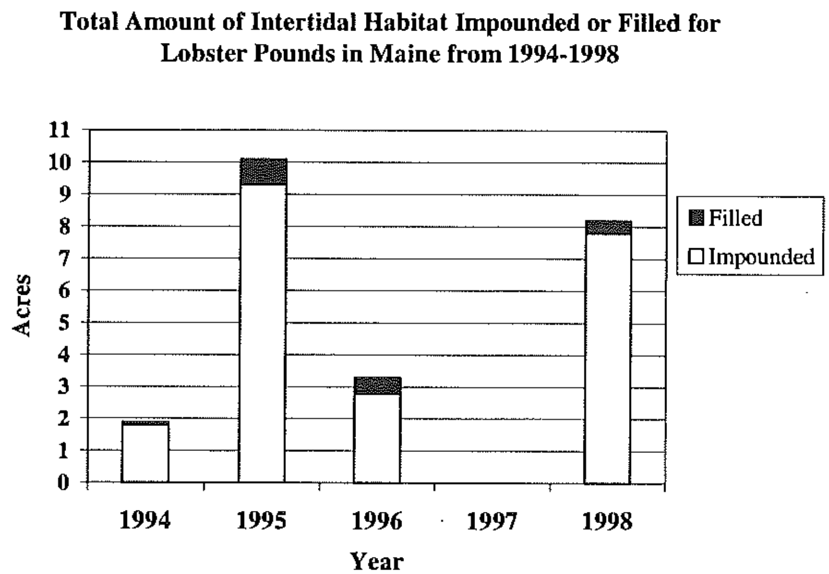
Many, if not most activities, cause multiple direct and indirect impacts. These activities may physically dredge, fill, cover, or scrape coastal wetlands as well as indirectly change water quality, restrict sediment movement or cause other damage to marine environments.

A good example of an activity that has multiple impacts to coastal wetlands in Maine is lobster pounds. Even though the number of new projects is low in comparison with other activities (Figure 1), the total area of impact of coastal wetlands is generally large and therefore requires a full NRPA permit. Lobster pounds are used to hold lobsters in the marine environment during the fall and winter months until the value of the fishery increases and an optimal price per pound can be guaranteed.

Seven acre lobster pound, Beals Island, ME

Since 1994, 23 acres of intertidal habitat have been impounded or filled for lobster pounds in Washington County (Figure 6). All pounds were constructed on intertidal fine sediments often characterized as having fringing salt marsh, annual eelgrass, rockweed, and commercially important species of soft-shelled clams, blue mussels, sandworms and bloodworms. For practical reasons, most lobster pounds are located within low energy environments such as mud flats in small bays and coves. A few are located on more exposed intertidal flats and a semi-circular or square berm or wall made from fill and rock is constructed extending off the land and out into the intertidal zone to trap water (e.g direct impact).

Figure 6.



Seawater is usually impounded (indirect impact) from September to April, changing an intertidal mud flat to a subtidal impoundment. As the tides change, seawater flows over the top of the impoundment adding new sources of salt water and removing fresh stormwater run-off. Thousands of pounds of banded lobsters are impounded (as many as 60,000 lbs. / 2 acres), fed, and, in some pounds, treated with antibiotics for several months. Sides of the pounds are steeply sloped and short wire mesh fencing is constructed to keep lobsters from crawling out of the impoundment. Most pounds contain surface or bottom aeration that indicates there is low dissolved oxygen in the water (indirect impact). Turbid conditions are maintained within the pound by the constant digging by the lobsters. Lobsters are harvested from the pounds by dragging and hand-picking by divers. In April, pounds are drained, cleaned and smoothed by rakes and bulldozers. Most are open to intertidal clamming and worming by recreational and commercial fisherman during the draw-down period. As time goes by, sediments hardened as fine sediments are removed by lobster activity, pound maintenance and water exchange. These actions and results all impact the former mud flats and may violate state water quality laws (Lee Doggett, personal communication).

TYPES & DISTRIBUTION OF INTERTIDAL HABITATS

Types and Acreage of Intertidal Habitats

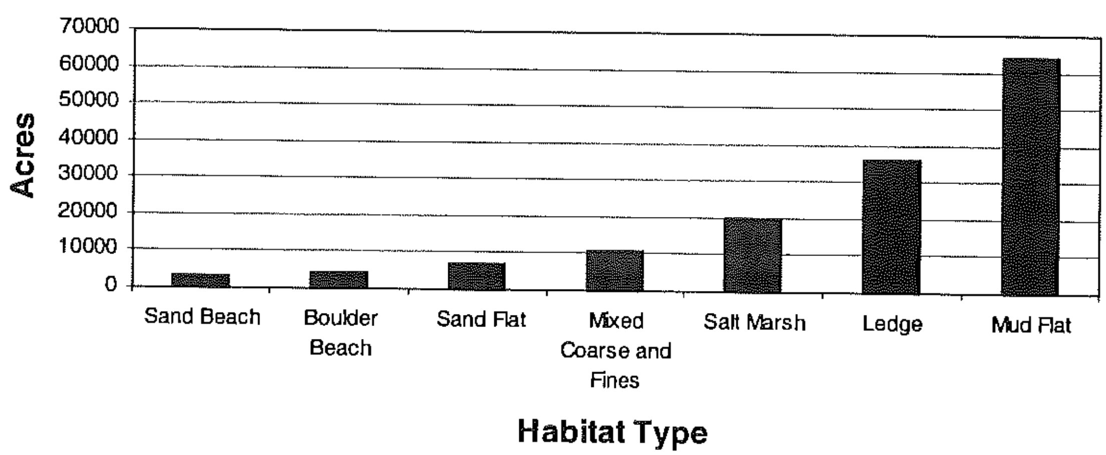
The Maine coastal landscape has a unique and diverse geological setting compared to other East Coast states. These geological formations are important in that they create the foundation of intertidal ecosystems that structure biological communities and form the base for commercial and recreational opportunities for Mainers (see next section). The length of the tidally influenced coastline of Maine measures approximately 5,300 miles (measurement estimated from 1:24,000 base maps provided by ME Office of Geographic Information Services). Its geological makeup is a complex mixture of bedrock headlands, rocky and sandy shores, barrier islands, barrier beaches, boulder fields, mud flats, and salt marshes. These geological features are partly a result of the advance and retreat of the Laurentide ice sheet accompanied by the drowning of the sea-coast during glacial times along with numerous other geological processes (Kelley et al. 1989). The Laurentide glaciation event spread over Maine to Georges Bank and only ended roughly 14,000 years ago on the coast. The advance and retreat of the glacier scoured the coastline of Maine, leaving behind ice-eroded rocky cliffs and substantial marine sedimentary deposits of gravel, sand and mud. The Presumpscot Formation, a glacial deposit of marine mud, sea-shells and drop-stones, prominent along the coast, was formed during this ice age (Kelley et al. 1989). Due to contemporary rising in sea level, bluffs of Presumpscot Formation currently erode along the Maine coast supplying coastal marshes, beaches and intertidal flats with new sources of muddy sediment (Fefer et al. 1980).

Although wave erosion of glacial deposits contributes the majority of new sediments to intertidal flats and beaches, additional sources of sediment are gained from rivers. In the spring, heavy rains and snowmelt flush river basins. Large volumes of water from the Kennebec and the Saco Rivers transport sandy glacial deposits onto mid-coast and southern beaches of Maine. Only these two rivers in Maine deliver large quantities of sand to the coast. Smaller rivers, such as the Penobscot, Royal and St. Croix Rivers, deliver muddy plumes of freshwater during spring and fall flood events into the Gulf of Maine (Kelley and Kelley 1995).

Daily intertidal and subtidal sediments are reworked by winds, waves, currents and tides. In bays and coves, sheltered from strong waves and currents, tides bring fine sediments into protected mud and sand flats. At high energy sand beaches in the late spring, summer and fall, wind driven circulation slowly bring sand and broken shells onto the beaches and sand dunes. During winter storms, sands are removed from the beaches and dunes and moved landward onto salt marsh (Kelley and Kelley 1995) or seaward. Off-shore deposits are formed in the winter, markedly altering the shape of the beach. Longshore transport currents, carry sands along the coast reworking the structure of the shore. For example, longshore currents create sand spits that extend offshore as well as transport sands inland filling the mouths of river channels (Kelley et al. 1995). This dynamic shifting of sands on high energy beaches create an unstable habitat for benthic marine life and, therefore, only adaptive species live in this environment.

There are a total of 145,069 acres of intertidal habitats in Maine (Figure 7, Table 1) (see Appendix B for data analysis). Mud flats are the most common and widely distributed intertidal habitat. Forty-four percent of all intertidal habitats are mud flats. Rocky headlands are the second most common geological feature along the shore. The bedrock headlands consist of granitic and metamorphic rocks created from ancient continental collisions (Kelley et al. 1989). Twenty-five percent of the shoreline of Maine is ledge. Off-shore islands contribute significantly to the total ledge acreage in Maine (Table 1). Correspondingly, there are 19,349 acres of tidally influenced salt marshes on the mainland and only 429 acres of emergent vegetated salt marsh on the offshore islands. Gravel beaches, coarse-grained flats, and mixed sand and gravel beaches are characteristic of mixed-coarse and fine flats that comprise 7 % on the intertidal shores.

Figure 7. Total Acres of Intertidal Habitat in Maine



Sand beaches, boulder beaches and sand flats are rare constituents of the intertidal zone in Maine. Only two percent of the total acreage of intertidal geology is sand beach. Sand flats are tidal flats composed of small sand grains slightly larger than the clay and fine sand sediments that characterize mud flats. They comprise only 5 % of the Maine shoreline. Boulder beaches, beaches that are dominated by boulders larger than 10" in diameter, make up only 3 % of the intertidal shore coastwide. Twenty-six percent of the total acreage of boulder beaches is located on offshore islands.

Table 1. Total acreage of intertidal habitats in Maine.

	Sand Beach	Boulder	Sand Flat	Mixed Coarse & Fine	Salt Marsh	Ledge	Mud Flat	Total
Mainland	2,719	3,035	6,744	8,400	19,349	26,839	61,169	128,255
Island	244	1,115	359	2,130	429	9,404	3,134	16,814
Total	2,963	4,150	7,102	10,530	19,778	36,243	64,302	145,069

Regional Distribution and Acreage of Intertidal Habitats

These diverse intertidal habitats are not distributed equally along the coast (Figure 8 & 9, Table 2). To help illustrate the spatial heterogeneity of Maine's coastal habitats, the state has been divided into four broad physiographic subsections, based on the distribution and nature of bedrock formations and glacial sediment supply (see Kelley 1987). For the complete list of habitat acreage by topographic quadrangle and regional groupings see Appendix B Table 3.

Table 2. Total acreage of intertidal environments in Maine by region.

Region	Sand Beach	Boulder	Sand Flat	Mixed Coarse & Fine	Salt Marsh	Ledge	Mud Flat	Total
Southwest (SW)	1,205	153	1,114	531	6,626	1,418	2,311	13,340
South Central (SC)	717	319	2,091	1,864	6,866	10,498	23,637	45,992
North Central (NW)	907	3,042	2,708	7,202	5,485	21,025	32,150	72,518
Northeast (NE)	134	636	1,190	951	800	3,302	6,205	13,219

Figure 8

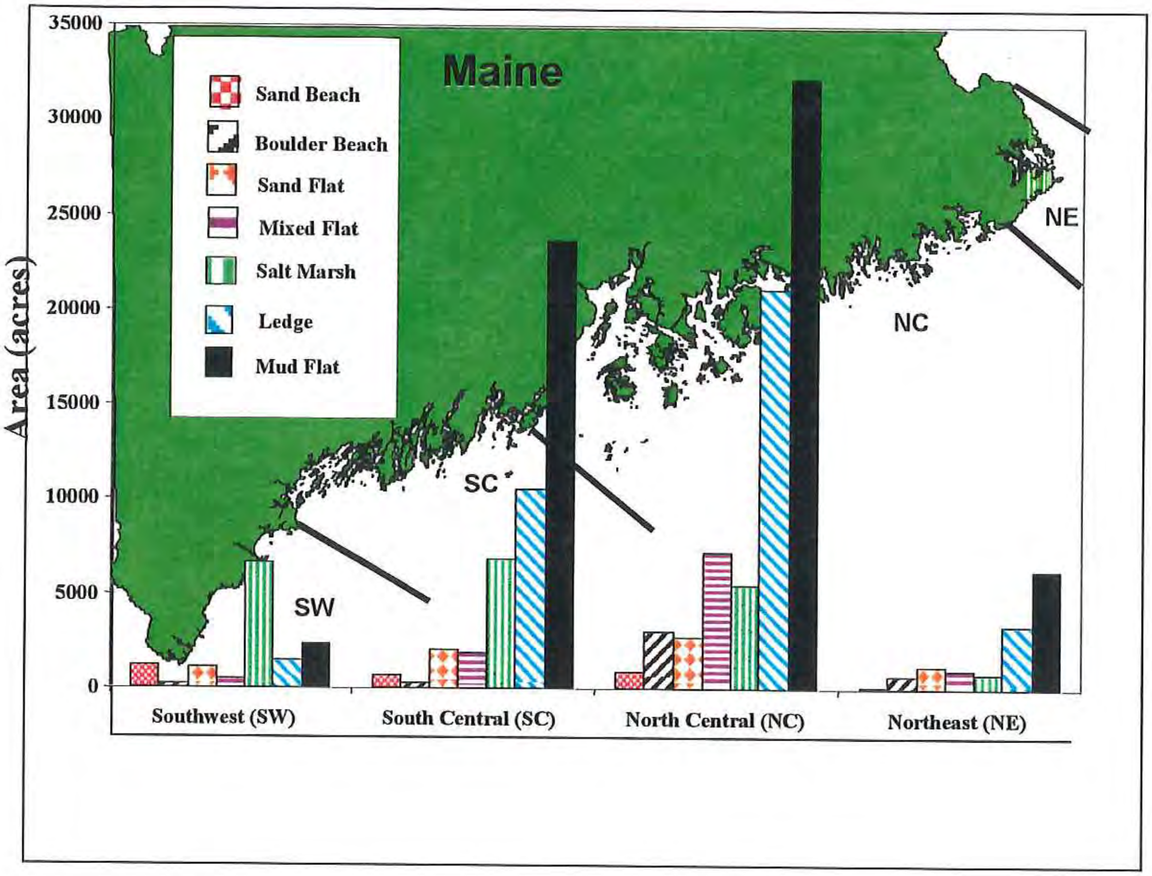
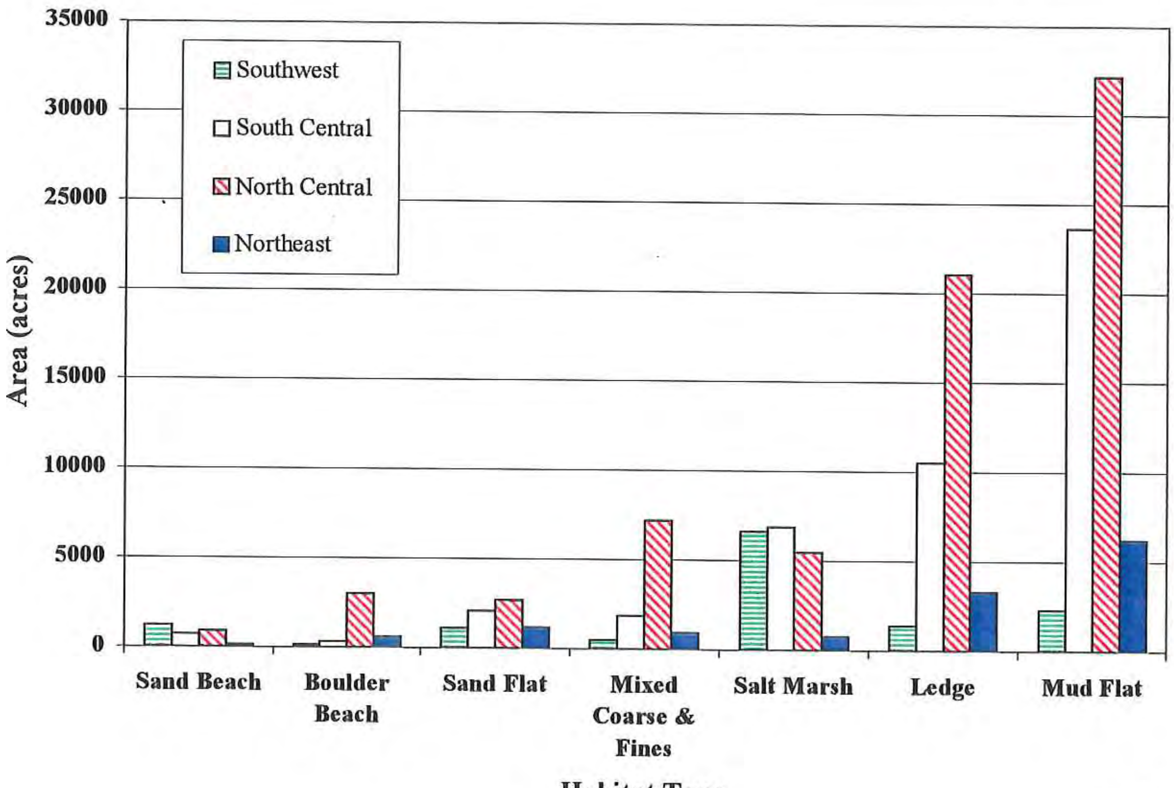


Figure 9



The southwest portion of the shoreline, from Kittery to Cape Elizabeth contains less than 8 % of the total acreage of intertidal environments in Maine. It is dominated by lush expanses of high salt marsh, barrier sand beaches, sand dunes and protective bluff headlands (Jacobson et al. 1987). Portions of the fine sediments that create the beach and marsh habitat are a result of slow erosion of the Presumpscot Formation (Jacobson et al. 1987). Over 40 % of the sand beaches and 34 % of the salt marshes in Maine are located south of Casco Bay. Unlike any other region in the state, this area is dominated by salt marshes. Fifty percent of the intertidal area in the southwest is high salt marsh. Sand beaches, supplied by the Saco River sediments, and salt marshes, characteristic of the region, are both located in Saco Bay between the sheltering rocky headlands of Prouts Neck and Biddeford Pool. In contrast to sand beaches and marshes, only 3.6 % of the total acreage of mud flat and 4 % of ledge statewide are south of Cape Elizabeth.

The South Central shoreline, also known as the "indented shoreline compartment" (Kelley et al. 1989) extends from Cape Elizabeth to Port Clyde. It is a region of large bays (e.g Casco Bay), inlets, broad flats, bedrock peninsulas, and numerous small islands and estuaries. The Kennebec, Sheepscot, Damariscotta, and Medomak Rivers are a few of the larger rivers that drain the upland and bring new sources of muddy sediment to the tidal flats of the upper estuaries. The total area of intertidal habitat in the South Central Region is 45,992 acres, representing 32 % of the total intertidal area in Maine.

Unconsolidated sediment flats, ledges and salt marsh are the prominent geological features within the South Central Region. Thirty seven percent of all mud flats in Maine are located here. Flats in Maquoit Bay, Middle Bay, Quahog Bay, Broad Cove, Sheepscot Bay and Muscongus Bay contribute to the majority of the mud flat area. Sand flats, like the broad sand flat of Sagadahoc Bay in Georgetown, constitute 4.5 % of intertidal habitat in this section. High salt marsh, like the extensive marshes surrounding Casco Bay and Popham Beach, account for 35 % of the tidal marshes statewide. Much of the sediments on the marshes in this region are derived from the erosion of the Presumpscot Formation (Jacobsen et al. 1987) and river sediments (Kelley et al. 1989). Bedrock peninsulas protect intertidal marshes and flats and slow wave energy from the Gulf of Maine. Bedrock ledges account for 23 % of the South Central shores.

Sand beaches in the South Central Region account for 24 % of the area of beaches statewide but only constitute 1.5 % of the total amount of intertidal area in this region. A majority of this area is composed of sandy spits located at the mouth of the Kennebec River. Beaches like Popham Beach and Sewell Beach in Phippsburg and Reid State Park in Georgetown are three of the few publicly accessible sand beaches of the mid-coast area. The drainage of the Kennebec River supplies new sources of sands to these beaches and spits.

The North Central Region, also known as the "island-bay complex" (Kelley et al. 1989) is the largest compartment extending from Port Clyde to Machias Bay. It contains 72,518 acres of intertidal shores. The coastline is dominated by a mixture of large irregular bays (e.g. Penobscot Bay, Frenchman Bay, Machias Bay), expansive mud flats, rocky cliffs, fringing low salt marsh, and large islands (e.g., Mt. Desert Island, Deer Isle, Vinalhaven).

Most sediment, in this region, is supplied from upland erosion of metamorphic rocks (Kelley et al. 1995). The outer granite ledges and islands are subject to a high degree of direct wave exposure from the Gulf of Maine and are not prone to weathering.

The North Central Region contains the greatest area, statewide, of ledge, mud flat, mixed coarse and fine flats, boulder beaches, and sand flats. The tidal range, the distance between the low and high tidal levels, is a principal factor that accounts for the increase in area of intertidal northern shores (Maine State Planning Office 1983). Tidal range in the North Central Region ranges from 9-14 feet while in the southwest it ranges between 7-9 feet (Kelley 1987). Half of all the mud flats in Maine are located in the North Central Region. Vast expanses of mud flats at Harrington, Addison and Machias Bay contribute to the total of 32,150 acres. Due, in part, to the rocky embankments surrounding the large islands, ledge in the region accounts for 58 % of the total acreage of rocky shores in Maine. Sixty-eight percent of all mixed unconsolidated flats are located here. These deposits are located in less exposed regions.

Although very small in proportion to the other habitats (4 %) in the North Central Region, 3,042 acres of boulder ramps and beaches account for 73 % of all boulder fields in Maine. The largest deposits are located in the Rockland, Brooklin, Barlett Island and Swan Island quadrangles. These deposits are located in highly exposed sites and undergo constant weathering. New additions to boulder fields, like the boulder beach at Monument Cove, Acadia National Park, are currently being added from the wave erosion of granite cliffs (Kelley and Kelley 1995).

Monument Cove, Acadia National Park, Mt. Desert.

Sand Beach, Acadia National Park, Mt. Desert.

Sand beaches and salt marshes only account for 1 % of the intertidal environments in the North Central compartment. Due to the limited sediment supply and other physical characteristics, only small patches of fringing marsh survive along protected river basins and bays (Jacobson et al. 1987). These low-marsh patches are dominated by *Spartina alterniflora* instead of *Spartina patens* and *Juncus gerardi,* two grasses typically representative of high salt marshes (Jacobson et al. 1987). The only major deposits of sand beach along the northern coast are located near Owls Head in the Rockland quadrangle (154 acres) and Roque Island and Sandy River Beach in the Jonesport quadrangle (184 acres). A small popular beach (<6.5 acres) at Acadia National Park on the eastern edge of Mt. Desert Island, is composed of broken shell fragments and sea urchins spines unlike the sand beaches of the south (Kelley et al. 1989). This beach, and other small eastern island beaches, are composed of broken shells from blue mussels, periwinkles, clams, barnacles, urchins and other hard-shelled invertebrates (see photo) (Kelley and Kelley 1995).

The Northeast Region, or "cliffed shoreline compartment" (Kelley et al.1989), runs from Machias Bay to Calais. It is only a few hundred miles in length (Kelley 1987) and has the smallest area of intertidal habitat. However, it has the greatest tidal range of any region ranging from 14-21 feet creating thousands of acres of intertidal shores (13,219 intertidal acres). Major portions of the shoreline are created from high volcanic cliffs and plutonic rock (Kelley 1987). The region only supports low fringing marsh in restricted protected coves (Jacobson et al. 1987).

Widespread unconsolidated flats and rocky cliffs dominate the eastern shores. Forty-seven percent of the coastal landscape is mud flat. The flats with the greatest acreage of habitat are located in Cobscook Bay surrounding Pembroke, Eastport and West Lubec. The largest mud flats are situated in Broad Cove (70 acres) and Carryingplace Cove (40 acres) in Eastport. The eastern flats characteristically become covered with a green filamentous algae known as *Enteromorpha intestinalis* each spring (Vadas and Beal 1987). Bedrock is the second dominant feature along the intertidal shoreline. The 3,302 acres of ledge act as a breaker of wind-generated waves from the bay and thus protect the estuarine habitats from erosion. Sand flats account for 9 % of the intertidal eastern shores and mixed coarse and fine beaches comprise 7 %.

Mud flat covered with *Enteromorpha intestinalis,* Eastport, ME

The Northeast Region has the smallest percentage of salt marshes and fine sand beaches in the entire state of Maine. There are only 134 acres of sand beach in the eastern section accounting for only 5 % of the sand beaches in Maine. The major deposits of sand beach, sand spits and swash bars are in the St. Croix River estuary and South Lubec. An unusual eroding glacial deposit of sand beach totaling nine acres in area is located on Dudley Island in Johnson Bay, Lubec. Only 800 acres of the fringing low salt marsh exist in the far eastern portion of the state, a mere 4 % of the tidal marsh statewide.

Significance of the Geology to Management

In summary, Maine's coastline has a great diversity of habitats but is only dominated by a few. Mud flats and ledge are the most common intertidal habitats, creating almost 70 % of the shoreline in Maine. A majority of the ledge and mud flats in Maine exist east of Cape Elizabeth. Sand beaches are the smallest constituent of intertidal geology in Maine. Almost all the sand beaches and emergent salt marshes lie in the south. Only small pocket beaches and fringing salt marshes exist Downeast due to the limitation of sources of sediment. Boulder beaches are also rare geological features in Maine. Most of the boulder beaches lie between Port Clyde and Machias Bay on unprotected off-shore islands. Sand flats only create 5 % of the Maine shoreline and are distributed throughout the state. Mixed coarse and fine flats make-up the rest of the coastline of Maine (7 %) and are concentrated on the shores of the irregular bays of the mid and east coast regions.

This information on the types and distribution of intertidal habitats is a foundation of data that provides the "big picture" of coastal geology. It should help in relating individual projects to the whole coastal and regional landscape. It provides information on which habitats are scarce or more plentiful statewide and by region. However, I do not advocate the misconception that less or more equals greater or lesser value and, therefore, should receive more or less protection. Instead, each site needs to be looked at individually from a functional point of view before any determinations can be made. From a biological perspective, the geology is the base and different environments have multiple levels of biological value (see next section). Even the same type of environment, doesn't always translate into the same biological importance statewide. For instance, some sand beaches in the south may have richer biological communities than sand beaches Downeast. This can be caused by geographical location, exposure, substrate, and numerous other factors (see introduction of next section). This is why general knowledge is not always enough, and site visits are necessary to determine habitat value.

FUNCTIONS, VALUES AND RANKINGS OF INTERTIDAL AND SHALLOW SUBTIDAL HABITATS

Introduction

For sound management, it is essential to clearly understand the biological differences and complexities of every intertidal and subtidal habitat subject to development. The following chapter addresses a series of questions about each major habitat type, and three vegetated habitats (eelgrass, rockweed, and kelp) and three shallow subtidal habitats (ledge, mixed coarse and unconsolidated sediments) not previously addressed. This section also lists the current threats to each habitat and provides a few suggestions for their future management. In addition, it includes a short section on the seasonal changes that can be expected within coastal marine habitats. This may be useful to assess the full potential of these habitats during the "off" season when species are dormant or absent.

The geological features of the coast, the physical and chemical characteristics of the seawater and the length of exposure to the sea, all influence the distribution of intertidal and subtidal marine plants and animals and the productivity of the site. The characteristics of the biological community are influenced by the physical location of the sediment or bedrock, geological features and texture of the substrate, wave and tidal energy, currents, light, water circulation, storm events, fresh water inputs, water temperature, salinity, predation, competition, ice and sand scour, over-fishing, disease, infections by bacteria and fungi, smothering by blooms of epiphytes and epifauna, availability of dissolved nutrients, and other biological, chemical and physical interactions. The species composition of soft bottom sediments is also influenced by organic content, water content, grain size, compaction, physical disturbance and oxygen penetration. Stable substrates, like bedrock, have a different species composition and density of animals than unstable shifting sediments. High intertidal regions favor organisms adapted to high exposure to air, wind, sun and fresh water. Subtidal species are less resistant and can not tolerate desiccation. Due, in part, to the decrease in length of time of exposure to atmospheric conditions, the diversity of marine fauna and flora increases as one approaches the subtidal. Distribution of subtidal species depends on the depth of the substrate and light penetration through the sea water. Due to biogeography, southwest intertidal and subtidal communities in Maine may have different assemblages of animals and algae than equivalent eastern communities (Mathieson et al. 1991). It should be clear that the variables driving or affecting intertidal and subtidal biota are many and complex.

Intertidal Habitats

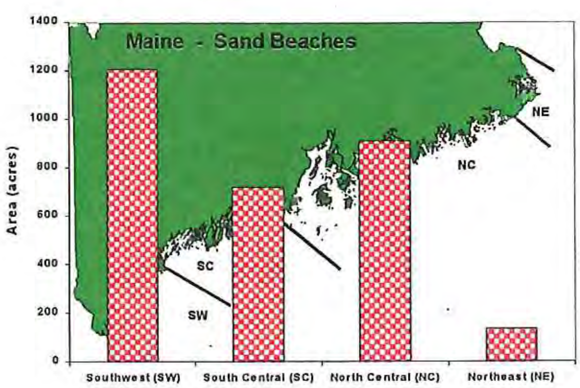
Functions and Values of Sand Beaches:

What are Sand Beaches?

Sand beaches are dynamic unstable high energy marine environments. Sand beaches are composed of fine quartz sands derived from glacial deposits and discharged from rivers and streams. In the southern portion of the state a majority of the sediments come from the Saco River (Kelley et al. 1989). Additional sediments wash ashore from off-shore subtidal basins (Fefer et.al 1980). Daily and seasonally sands are shifted in the surf by wind, waves and currents. Gentle wind and wave action deposit sands onto beaches and dunes in the summer. Storms remove sands from the beaches in the winter dramatically altering the slope of the beach. Longshore transport currents, carry sediments up and down the coast constantly overturning sediments.

Where are Sand Beaches Located In Maine?

There are approximately 3,000 acres of sand beach on the coastal mainland and offshore islands in Maine. Sand beaches only total 2 % of all intertidal habitats in Maine. Of that 2 %, 40 % of all sand beaches is located on the southern coast south of Casco Bay. The concentration of southern beaches is between Kittery and Cape Elizabeth.



Twenty-four percent of the sand beaches statewide is located within Casco Bay and Muscongus Bay. In contrast to the southern coastal landscape, the longest stretches of beach along the south-central coast are only located at Popham Beach and Sewell Beach in Phippsburg, Reid State Park in Georgetown and Pemaquid Beach in New Harbor. Large sand beaches become rare as one travels east. Small pocket beaches can be found at Owls Head, Acadia National Park, Lincolnville, Roque Island, Sandy River in Jonesport, and within the St. Croix River estuary.

What are the Functions of Sand Beaches?

Sand beaches support a high population of small invertebrates, bacteria and algae specially adapted to thrive in a constantly shifting environment. Bacteria, diatoms, and blue-green algae live in between sand grains and provide food for microscopic protozoans, crustaceans, invertebrate larvae and roundworms (Berrill and Berrill 1981). Low intertidal zones of sand beaches, which are protected from extreme heat and freezing temperatures, have high concentrations of small invertebrates (e.g., amphipods, isopods, clams, polychaete worms, oligochaete worms, cumaceans) important for food chain interactions (Larsen and Doggett 1990). These zones are essential foraging areas for gulls, terns and 23 other species of migrating shorebirds (Brown 1993; USF&W 1980). Amphipods, also known as beach-hoppers, living in the high intertidal wrack line, break down organic plant matter and provide additional food for shorebirds.

Sand beaches function as critical resting sites for shorebirds during their long northerly and southerly migration. They are roosting habitat for at least 19 species of shorebirds (USF&W 1980).

The endangered species, piping plover and least tern, nest and breed on sand dunes above the high intertidal zone of sand beaches between May and August. Beaches are wintering habitat for purple sandpipers (USF&W 1980).

What are the Economic and Recreational Values of Sand Beaches?

Sand beaches in southern coastal townships are an important recreational area for residents and tourists. Long stretches of sand beaches support an entire tourism industry based on swimming, sun bathing and relaxation. Small towns, like Old Orchard Beach, rely on the natural beauty and benefits that sand beaches provide to encourage tourism and commerce within their region. The aesthetic allure of sand beaches and high energy surf raises the value of commercial and private shorefront property.

Commercially harvested species of soft-shelled clams, surf clams (in the shallow subtidal), blood worms, sand worms, and periwinkles are found in low abundance on some sand beaches.

How Sensitive are Sand Beaches to Disturbance and Development?

Sand beaches have different classifications based on their intertidal zonation (see Habitat Rankings). Low intertidal areas are ranked by the Dept. of Environmental Protection as having a high sensitivity to development and disturbance. They are areas containing high concentrations of small invertebrates that are essential food for migrating shorebirds. Mid and high intertidal areas are classified as moderately sensitive to disturbance but economically valuable. Heavy wave and current action, mixing sands, and high exposure to wind, rain, freezing temperatures and sunlight make these intertidal zones less productive and diverse.

Sand beaches, due to the high wave energy, can recover relatively quickly from low impact activities like jogging or digging.

What are the Threats to Sand Beaches?

- Dredging, dragging, scraping, or other major physical disturbances: Disturbances can liberate toxics and nutrients from sediments into the water column. Channel dredging and scraping removes sediments, which may lead to increased coastal erosion and loss of breeding habitat for shorebirds.
- Disturbance of nest sites: Shorebirds, like the endangered piping plover, nest and feed on sand beaches in the spring and summer. Any major or minor disturbance (e.g. walking on the beach) can cause them to abandon the nest.
- Seawalls and other shoreline stabilization barriers (e.g., rip-rap): As sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Other physical barriers: Any structures (e.g., groin, dam, culverts, bridge) that change current or tidal flows or direction, alter salinity, disrupt travel corridors for animals, modify drainage of the beaches, increase scour, prevent sediment movement and larval and fish passage threaten the survival of sand beaches.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.
- Water Quality Alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect sand beaches. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Cumulative impacts: Over-development of areas adjacent to sand beaches reduces acreage of unspoiled beaches; reduces drainage areas; attracts more people to the coast; increases disturbance, erosion and stormwater run-off; reduces public access; leads to additional armoring of the shore and threatens wildlife.
- Pipe laying: Loss of sand beach habitat under the pipe and the potential impact from any waste discharged from the pipe. Depending on the size of the pipe, it may also interfere with the natural movement of sand.

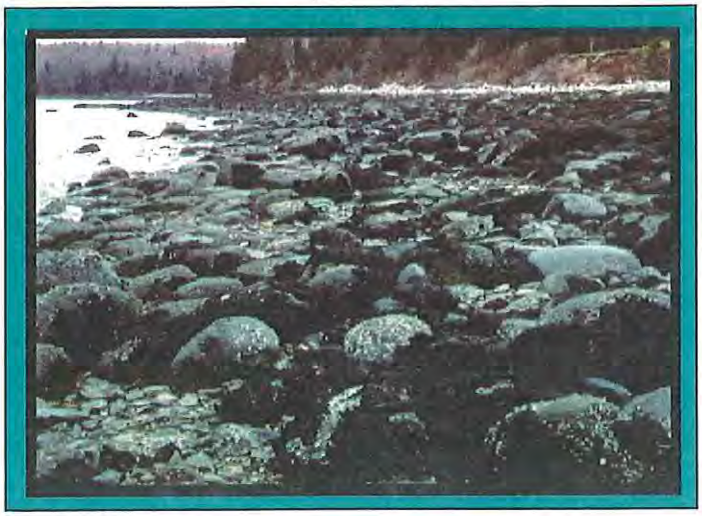
What are the Permitting Issues of Sand Beaches?

- Disturbance on sand beaches should be avoided during spring and fall shorebird migrations and during the breeding season (late spring and summer). The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).
- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around sand beaches. No filling should be permitted without proper compensation.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. Sediment movement and transport must be mapped before licensing any structure. Barriers should never extend into the subtidal.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.

Summary of the Functions and Values of Sand Beaches.

Functions	**Values**
1. Production of animals on and within the sand	Essential foraging habitats for migrating shorebirds Supports the food web Supports commercial fisheries
2. Recreational	Supports multi-million dollar tourism industry Aesthetically pleasing High recreational and educational value
3. Essential habitat for birds	Foraging, roosting and staging areas for migrating shorebirds, gulls and terns Wintering areas for purple sandpipers
4. Primary production from benthic diatoms and blue-green algae	Improves water quality Binds sediments therefore reducing erosion Fuels benthic food web Supports commercial fisheries and wildlife
5. Recycling of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
6. Rare plant and animal habitat	Nesting and feeding ground for endangered piping plovers and least tern Rare plant habitat

Functions and Values of Boulder Beaches:

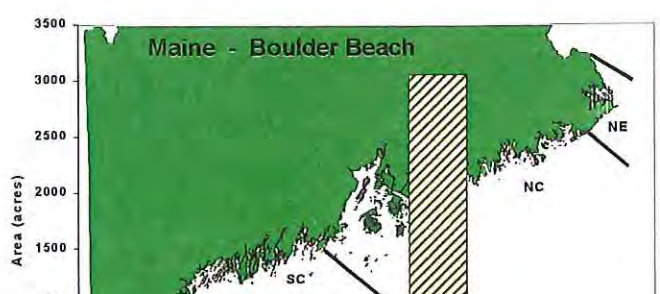


What are Boulder Beaches?

Boulder beaches and boulder ramps are partially exposed beaches that are primarily composed of round boulders between 10 inches and 10 feet in diameter. The boulders are large enough to resist being over turned by wave action. Many of the beaches lie adjacent to ledge outcrops. Boulder beaches were formed by glacial scouring and deposition and bedrock erosion. In areas that receive a high degree of direct wind and wave expose from the Gulf of Maine, the weathering of the granite ledges slowly resupplies the beaches with additional boulders. Underneath each boulder lies a thick layer of coarse and fine sediments for infaunal communities.

Where are Boulder Beaches Located in Maine?

Boulder beaches are scarce marine habitats in Maine. Less than 3 % (4,150 acres) of all the intertidal shoreline in Maine is composed of boulders with over 27 % of the acreage located on offshore islands. Approximately 90 % of the beaches is located within and north of Penobscot Bay. The largest deposits are found in Rockland, Brooklin, Barlett Island and Swan Island. Smaller deposits are located on Bailey Island, Monument Cove on Mt. Desert Island, Lincolnville and West Quoddy Head St. Park.



What are the Functions of Boulder Beaches?

Boulder beaches are one of the most diverse intertidal habitats (Larsen and Doggett 1981). The boulder fields function as a stable environment for the attachment of algae and organisms. Animals seek shelter underneath the boulders, within the coarse and fine sediments and within and underneath the covering of kelps, rockweeds, and Irish moss (see rockweed and kelp for additional functions). Primary production from macroalgae is high as well as secondary production from epifauna and infauna. Polychaete worms, oligochaete worms, flatworms, clams, amphipods, isopods, crabs, roundworms, ribbon worms, scaleworms, limpets, barnacles, periwinkles and dog winkles all colonize boulder beaches. These small organisms feed fish and birds and contribute to the biodiversity of the marine ecosystem. Unique intertidal species such as sea spiders, spider crabs, brittle stars, sea cucumbers and nudibranchs (sea-slugs) that are sensitive to environmental and anthropogenic influence are found in low intertidal zones on boulder beaches. Small fish such as the rock gunnels and sculpins forage and seek shelter on boulder beaches (Brown 1993). Boulder beaches export plant and animal detritus to offshore and upper intertidal communities for microbial food webs. Boulder beaches intercept large sea swells and slow shoreline erosion.

Boulder beaches are foraging habitat for eight species of shorebirds, waterfowl and gulls. They also function as roosting habitat during long migrations for ten species of shorebirds (USF&W 1980).

Purple sandpipers use boulder beaches as wintering habitat (USF&W 1980).

What are the Economic Values of Boulder Beaches?

Boulder beaches contribute to the production of commercial species such as lobsters, blue mussels, periwinkles and sea cucumbers. Low intertidal zones function as nursery grounds for juvenile lobsters and foraging habitat for fish during high tide. Ascophyllum, Irish moss and kelp is sometimes harvested from boulder beaches.

How Sensitive are Boulder Beaches to Disturbance and Development?

Boulder beaches have three DEP sensitivity classifications for three different intertidal zones (see Habitat Rankings). Low intertidal zones of boulder beaches with algal cover have high species diversity and support species not found commonly in other intertidal habitats. These areas have been classified as highly sensitive to disturbance. Mid intertidal zone with no algae are less diverse and have fewer commercial and ecological functions; therefore they are classified as moderately sensitive to disturbance. Dry, exposed, barren high intertidal boulder beaches support few intertidal species. These areas can recover from physical activities and are therefore classified as having a low sensitivity to disturbance and development.

What are the Threats to Boulder Beaches?

- <u>Shading from physical structures</u>: Shading blocks light and reduces algal growth.
- <u>Removal and/ or disturbance of habitat</u>: Dredging, removal of boulders, impoundment of water and sediment loading smothers or removes boulder habitat. Loss of boulders equals a loss of shelter and feeding areas for animals.
- <u>Pollution</u>: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, oil pollution, stormwater run-

off, sewage, airborne pesticides from agriculture and others all damage boulder beaches. In addition, phytoplankton blooms caused by nutrient loading from pollution cause reductions in light levels harming algal beds on boulders.

- Resuspension of sediments: Resuspension of sediments from dredging, filling, boating and fishing activity smother boulder habitat. Resuspension of sediments may resuspend larvae and small invertebrates changing the community structure of the habitat and endangering algal beds.

What are the Permitting Issues of Boulder Beaches?

- Avoid permitting activities that remove boulders or shade environments.
- Avoid permitting activities in the low intertidal and shallow subtidal.
- Permit activities in high intertidal zones and mid intertidal zones without algae cover.
- Water dependent structures should be placed in areas that will not shade algae or indirectly impact algal beds. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade beds associated with boulders.
- Consider removing boulders and any associated lobsters and placing them in adjacent habitats before construction.
- Avoid sediment disposal on or around boulder beaches. Avoid activities that will resuspend sediments around algal beds.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around boulder beaches.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Intertidal Boulder Habitats.

Functions	Values
1. Production of animals on rocks, under rocks, in sediments under boulders, on and within algal beds	Supports commercial fisheries Supports the food web Supports recreational sport fishery Support shorebirds, seabirds, and sea ducks
2. Permanent and stable attachment sites for primary producers (see kelp / rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Roosting sites and wintering habitat for birds	Helps sustain healthy populations of shorebirds, sea birds, and sea ducks
4. Intercepts and slows currents and waves	Reduces shoreline erosion of nearshore habitats Increases sedimentation
5. Nursery and spawning ground	Promotes and sustains lobster populations Helps sustain mussel populations Maintains balanced ecosystem
6. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
7. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
8. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
9. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
10. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats Supports tourism industry

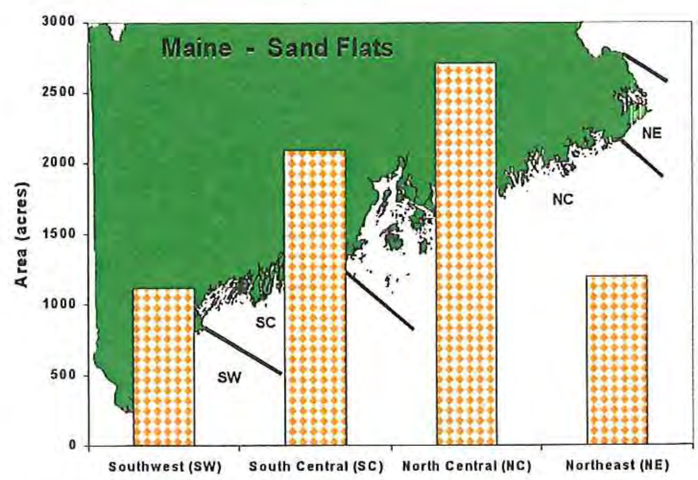
Functions and Values of Sand Flats:

What are Sand Flats?

Sand flats, like mud flats, are sensitive habitats sheltered by rocky headlands, islands, and sand barriers. Most sand flats are located in coves, bays and estuaries. They receive greater wave energy and tidal currents than mud flats preventing the fine silt and clays from settling out of the water column. Only the larger sand grains and organic detritus remain on the intertidal flats (some sand flats may have a small portion of silts and clays mixed with sand). Sand flats can be distinguished from mud flats by the coarser nature of the sediment as well as the sand waves that appear on the surface during ebb tide (see photo above). They receive sediments from the same sources as mud flats.

Where are Sand Flats Located in Maine?

Sand flats are scarce in Maine. Only 5 % of the shoreline of Maine is sand flats. Eight-five percent of the 7,102 acres of sand flat is located north of South Portland. The largest sand flats are found in Sagadahoc Bay and Heal Eddy, Georgetown; Gerrish Island, Kittery; Bailey's Mistake, Trescott; and Clam Cove, Rockport (Larsen and Doggett 1981).



What are the Functions of Sand Flats?

Sand flats support large populations of filter feeders, sediment deposit-feeders, grazers, and predatory worms and crustaceans. In comparison with other intertidal habitats, sand flats have the second highest mean species diversity (Larsen and Doggett 1981). Sand flats, like mud flats, are marine sediment soups of microscopic algae, bacteria, and animals contributing to primary and secondary productivity, organic breakdown, nutrient recycling, and scour reduction. Large populations of amphipods, polychaete worms, clams, oligochaete worms, round worms, isopods, cumaceans, bivalves, crabs, Capitellid worms, sand shrimp, hydrobia snails, dog whelks, moon snails and hermit crabs settle, forage and breed on intertidal sand flats (Brown 1993; Larsen and Doggett 1981). Often flats are colonized by eelgrass and their associated fauna and flora (see Eelgrass). Mummichogs, sticklebacks, silversides and other small fish feed on flats during high tide. They are nursery grounds for finfish, sand shrimp, clams and other invertebrates. Like mud flats, sand flats slow tidal and wave energy buffering the upland against tidal erosion and lessening impacts from storm surge events.

Sand flats are critical feeding areas for 24 species of migrating shorebirds, waterfowl, wading birds and gulls. Sand flats are roosting and resting sites for 19 species of shorebirds (USF&W 1980).

What Are the Economic Values of Sand Flats?

Sand flats contain commercially important populations of sand worms, blood worms, sand shrimp, periwinkles, blue mussels, quahogs, razor clams and soft-shelled clams that were valued at over $11 million upon landing in 1997 (NOAA 1997).

In addition tidal sand flats are foraging areas for commercially and recreationally important species such as winter flounder, Atlantic herring, rainbow smelt, alewife, and Atlantic mackerel valued at over $ 8 million upon landing in Maine in 1997 (Brown 1993; Whitlatch 1982; NOAA 1997).

How Sensitive are Sand Flats to Disturbance and Development?

Based on their high commercial and ecological values and their slow recovery rates from physical disturbance, sand flats are classified by DEP as a high sensitivity habitat (see Habitat Rankings).

What are the Threats to Sand Flats?

- Filling of sand flats: Filling results in a direct loss of intertidal habitat.
- Dredging, dragging or other major physical disturbances: Disturbances can liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion. Dragging kills epifauna and encourages the spread of opportunistic species.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.
- Seawalls and other shoreline stabilization barriers (e.g. riprap): Sand flats require continual sources of sediments from upland and coastal erosion. Without renewable resources of fine grain sediments entering these regions, surface layers of sand flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Water Quality Alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect sand flats. Pollutants from point and non-point sources can change communities of infauna and epifauna.

- Lobster pound creation / Impoundment of water: impoundments convert intertidal areas into subtidal areas by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and the reduction of species diversity within the benthic and algal communities.
- Other physical barriers: Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of the flats, prevent sediment movement and larval and fish passage threaten the survival of sand flat communities.
- Pipe laying: Loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Sand Flats?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around sand flats. No filling of sand flats should be permitted without proper compensation. Large machinery should not be allowed on sand flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of sand flats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on sand flats should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Sand Flats (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Production of animals on and within the mud or sand	Supports commercial species Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion / resuspension Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercially important fish Roosting and staging areas for migrating shorebirds

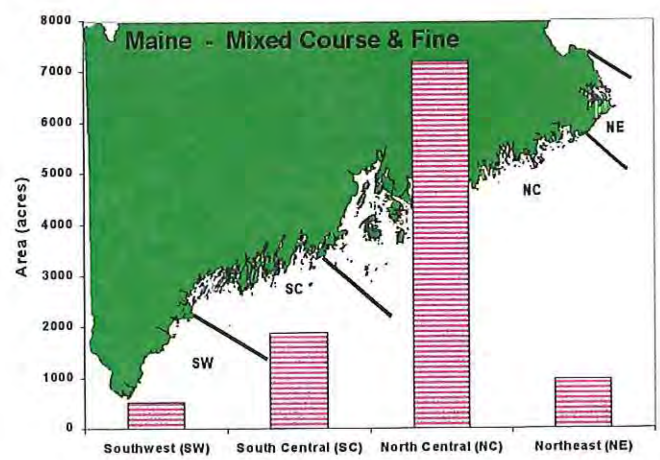
Functions and Values of Mixed Coarse and Fine Flats:

What are Mixed Coarse and Fine Flats?

Mixed coarse and fine flats are intertidal flats with a mixture of gravel, cobble, boulder, sand, shell, organic detritus, silt and clay sediments. Due to the large number of attachment sites on the rocks, these flats are characteristically covered in rockweed or other macro algae. Low intertidal areas may have Irish moss or patches of kelp attached to larger cobbles and boulders. The wave energy can vary depending on the location of the flat. Exposed sites with an unlimited fetch will have a greater percentage of coarse-grained sediments. Protected mixed coarse and fine flats will have a higher percentage of fine clays, silt and sand. Mixed flats are unstable environments where rocks, sediments and associated fauna are tossed around during heavy wave action.

Where are Mixed Coarse and Fine Flats Located in Maine?

There are 10,530 acres of mixed coarse and fine intertidal flats in Maine. Twenty percent of the total acreage is located on offshore islands. Most of the mixed flats are located in the north-central portion of the state from Penobscot Bay to Machias Bay. Less than 5 % of the mixed flats are found south of Portland. Most of the far southern flats are located near Kittery, Biddeford Pool and Wells. In the south-central portion of the state a majority of the mixed flats, totaling 1,022 acres, are situated between Portland and Bailey Island. Jonesport (371 acres), Machias Bay (525 acres) and Eastport (422 acres) have the largest area of mixed coarse and fine flats statewide.



What are the Functions of Mixed Coarse and Fine Flats?

Mixed coarse and fine flats have similar functions as sand flats and mud flats however they usually support fewer numbers of animals and are less biologically diverse. Mixed flats support populations of benthic algae, bacteria, and small invertebrates that contribute to the health of the marine ecosystem. Snails, amphipods, isopods, polychaete and oligochaete worms, nematodes, earwigs, barnacles, limpets, moon snails, nudibranchs, small clams , hydroids, dog winkles, and hermit crabs, sand shrimp, oysters, and tube worms live in or on mixed coarse flats in Maine (Larsen and Doggett 1981). Macro-algae and eelgrass and their associated fauna and flora often colonizes mixed flats increasing the functions and values of the habitat (see Rockweed and Eelgrass). Small fish like mummichog and sticklebacks that are prey to top consumers, forage during flood and ebb tides. Amphipods, also known as beach-hoppers, living in the high intertidal wrack line, break down organic plant matter and provide food for birds. Mixed coarse and fine flats are foraging habitat for 24 species of shorebird, American black ducks, great blue herons, and wading birds, terns and gulls (USF&W 1980).

Mixed flats function as roosting habitat for 19 species of shorebirds (USF&W 1980).

Between April and June, these flats are nesting sites for spotted sandpiper. In the winter, purple sandpiper live on mixed flats (USF&W 1980).

Gravel beaches and cobble beaches, classified under mixed coarse and fine flats for this report, have fewer numbers of species as mixed flats. Gravel and cobble beaches are less protected from sea swells and have only a small percentage of fine grained sediments. Most are completely unvegetated. Cobble and gravel are constantly rolled by waves creating an environment that only few species can colonize. The diversity is lower but the production of the few adaptive species such as oligochaete, flat, and nemertean worms, is often high.

Cobble beach near Seal Harbor, Mt. Desert Island.

What are the Economic Values of Mixed Coarse and Fines?

Mixed coarse and fine flats are heavily harvested in Maine for soft-shelled clams, sand worms, and blood worms. Mixed flats also support populations of lobsters, quahogs, periwinkles, blue mussels, Irish moss, knotted wrack, kelp, rock crabs, and mud shrimp (Brown 1993). Mixed flats contributed to landings valued at over $150 million in 1997 (NOAA 1997).

Lobsters nursery grounds are located in low intertidal zones. Juveniles live under cobbles and boulders. The greatest population density in the intertidal area is between May and November. Adult lobsters, greater than 6 years old, move offshore in the winter while juveniles remain in low intertidal rocky environments. Adults return to the intertidal habitat in the late spring and summer (Diane Cowan, personal comm.).

How Sensitive are Mixed Coarse and Fines to Disturbance and Development?

The ecological sensitivity of mixed coarse and fine environments depends on the location within the intertidal zone. Low intertidal zones are classified by DEP as having a moderate to high sensitivity to disturbance (see Habitat Rankings). These areas are lobster nursery grounds and regions of high abundance and diversity of fauna. However, mid and high intertidal zones, with no red or brown algae, are classified as low sensitivity. These areas have fewer functions and values and support small populations of opportunistic species.

What are the Threats to Mixed Coarse and Fines?

- Filling of flats: Filling results in a direct loss of intertidal habitat.
- Dredging, dragging or other major physical disturbances: Disturbances can liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.
- Seawalls and other shoreline stabilization barriers (e.g. rip-rap): Flats require continual sources of sediments from upland and coastal erosion. Without renewable resources of fine grain sediments entering these regions, surface layers of mixed flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect mixed environments. Fresh water discharges especially impact lobster nursery grounds. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Lobster pound creation / Impoundment of water: Lobster pounds converts intertidal area into subtidal area by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and the reduction of species diversity within the benthic and algal communities.
- Other physical barriers: Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of the flats, prevent sediment movement and larval and fish passage threaten the survival of animals in mixed environments.

- Pipe laying: Laying of pipe leads to the loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Mixed Coarse and Fines?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around flats. No filling of mixed coarse flats should be permitted without proper compensation. Large machinery should not be allowed on lower intertidal regions of mixed flats.
- If feasible, restrict activity to upper intertidal shores or unvegetated mid intertidal zones.
- Choose to disturb unvegetated gravel or cobble beaches over finer more diverse mixed flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of mixed flats.
- New developments or activities in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff to flats. Fresh water will kill juvenile lobsters and marine fauna.
- Disturbance on mixed coarse and fines should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Mixed Coarse and Fine Flats (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Production of animals on and within the sediment and under rocks	Supports commercial shellfish and worm fishery Supports lobster fishery Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercial fish and lobsters Roosting and staging areas for migrating shorebirds Nesting sites for spotted sand piper Winter habitat for purple sandpiper

Functions and Values of Salt Marsh:

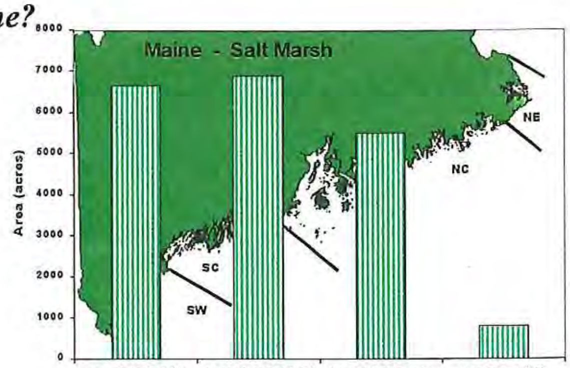
What is Salt Marsh?

Salt marshes are one of the most productive habitats on earth (Kneib 1997). Salt marshes are persistent marine nearshore emergent grass habitats. They lie between the upland and intertidal flats and beaches in protected bays and coves, along tidal rivers or behind barrier beaches. Marshes can exist at the same location for up to 4,000 years. The salinity ranges between 0.5 - 34 parts per thousand (ppt). Marshes occur in low energy habitats with sources of fine grained sediments. Tidal marsh plants, marine and terrestrial plants and algae decompose and combine with mineral sediments to form large salt marsh peat deposits (Bryan et al. 1997).

There are three major types of salt marsh: back-barrier marshes, finger marshes and fringe marshes. Each type may contain a variety of marsh types from low marsh, dominated by cordgrass (*Spartina alterniflora*) to high marsh, dominated by salt meadow grass (*Spartina patens*) and black grass (*Juncus gerardii*). Low marsh is flooded by salt water twice daily while high marsh is only flooded irregularly by spring tides. Back-barrier marshes, like the Wells or Popham Beach marshes, are large high marshes located inland of a barrier beach. Finger marshes, border tidal channels and rivers, and fringe marshes are small patchy marshes dominated by low marsh flora on river banks and on upper shores of coastal flats (Bryan et al. 1997).

Where is Salt Marsh Located in Maine?

Statewide there are 19,778 acres of salt marsh on the mainland and offshore islands of Maine. Like sand beaches, most of the expansive high salt marshes are located in southern Maine. Approximately 13,500 acres or 68 % of the total acreage are located south of Penobscot Bay. Fifty percent of the intertidal area south of Portland is composed of salt marsh.



A majority of the larger marshes can be found between Wells and Cape Elizabeth and behind Popham and Seawall Beach in Phippsburg. In comparison, less than 8 % of the intertidal area north of Penobscot Bay is comprised of salt marsh. The eastern salt marshes occur in small fringing patches along river mouths and protected bays and coves. Significant salt marshes border estuaries like the Pleasant River in Washington County.

What are the Functions of Salt Marsh?

Salt marshes have myriad biological, chemical, and geological functions in marine systems. Tidal marshes in the summer are great primary producers converting nutrients into vascular plant growth and diatom mats. Salt marshes produce oxygen. The tall plant canopies provide food and shelter for terrestrial birds and shorebirds, shellfish, and invertebrates. During high tide, they are feeding grounds for mummichog, stickleback, killifish, tomcod, Atlantic silversides, cunner, rock gunnel, sand lance and other important forage fish. They are nursery areas for shellfish, insects and other invertebrates. Large populations of flying insects like mosquitoes breed in marshes providing vital food resources for birds and fish. Plants provide structure for the settlement and proliferation of epiphytes. Marsh plants trap and bind marine and terrestrial sediments increasing shoreline elevation and buffering the upland from coastal erosion caused by sea level rise and periodic storm events. The salt marsh absorbs flood waters reducing storm damage in the upland. Salt marsh ecosystems, by slowing water movement, improve water quality by filtering out sediments, storm water and other pollutants and storing them in peat deposits. Marsh ecosystems harbor billions of bacteria that break-down dead organic matter and release nutrients into the water column for uptake by plants and algae. In the fall and winter, dead plant matter is exported into the nearshore marine ecosystem fueling intertidal and subtidal food chains (Nixon 1982; Bryan et al. 1997).

The salt marsh in some parts of Maine can support populations of rare plants such as bulrush (*Scirpus cylindricus*), spike rush (*Eleocharis rostellata*), horned pond-weed (*Lannichellia palustis*), water pimpernel (*Samolus parviflorus*), gerardia (*Gerardia maritima*), marsh-elder (*Iva frutescens*), pipewort (*Lilaeopsis chinensis*), and monkey flower (*Mimulus ringens*) (USF&W 1980).

Amphipods, living in the wrack line at the base of the salt marsh, break down plant matter and provide food for migrating and breeding shorebirds, gulls, and terns.

Mammals forage and live within salt marsh vegetation. Marshes are habitat for field mice and screws. Mink, skunk, raccoon, muskrat and weasels forage on mice, eggs, vegetation and shellfish during low tide (Nixon 1982).

Habitat dependent species, such as *Orchestia uhleri* (amphipod), *Melamus bidentatus* (snail) and ribbed mussels (*Gukensia demissa),* are specially adapted to live within cordgrass zones. These species are not found outside of this habitat.

What are the Economic and Recreational Values of Salt Marsh?

The salt marsh supports commercial and recreation fisheries. Shellfish and finfish that feed and mature within salt marshes for a portion of their lives were harvested and landed for $11 million in 1997 (NOAA 1997). American eel, Atlantic herring, alewife, American shad, rainbow smelt, white hake, bluefish, Atlantic mackerel, butterfish, and winter flounder may spend a portion of their lives in tidal marshes (Wells 1998).

Recreationally, the attractive landscape and its associated animal life encourages boating, sport fishing, hunting, canoeing, kayaking, hiking, sightseeing, bird watching and other recreational activities. Sport fish, such as brown trout, brook trout, bluefish and striped bass forage in salt marsh habitat.

Atlantic salmon, an important recreational sport fish, forage in the salt marsh.

Tidal marshes are used as outdoor classrooms for students and nature enthusiasts. Some archeological sites exist on or near salt marshes (Bryan et al. 1997).

What Additional Ecological Uses do Salt Marsh Provide?

Salt marshes are critical staging, foraging and sheltering environments for many different types of birds. Salt marshes contain populations of insects, worms, crabs, bivalves, small fish and other benthic invertebrates that attract predators. They are foraging areas for 21 species of shorebirds, six species of heron, four species of egret, two bitterns, glossy ibis, Canada geese, marsh hawks, sparrows, swallows, swifts, gulls, terns, and other small terrestrial birds and waterfowl (MIF&W 1994; Nixon 1982; USF&W 1980). American Bittern, a species of special concern, use salt marsh. Hawks, owls, osprey and other raptors forage on mammals, fish and insects in salt marsh habitat.

Drier high intertidal portions of the salt marsh are nesting habitat for terns, piping plovers, willet, marsh hawk, short-eared owl, geese, clapper rails, sparrow, gulls, waterfowl, and others (Nixon 1982).

Marshes also function as roosting habitat for 21 species of shorebirds during long fall and spring migrations (USF&W 1980).

How Sensitive is Salt Marsh to Disturbance and Development?

Salt marshes, including fringing salt marshes, are productive and diverse habitats that are classified by DEP as having a high sensitivity to disturbance and development (see Habitat Rankings).

What Are the Threats to Salt Marsh?

- Shading from physical structures: Shading blocks light and reduces growth of salt marsh plants.
- Physical barriers or direct alteration: Any structures (e.g. groin, seawall, dam, culvert, flap gate, bridge, road) or physical alterations (e.g. ditching, fill, draining) within the salt marsh or adjacent to the salt marsh that can change or restrict current, fresh water, or tidal flows or directions; alter salinity or oxidation of soils; disrupt travel corridors for animals; alter drainage, flooding, or elevation of the marsh; increase human activity and disturbance; prevent sediment movement; and restrict dispersal of plants, fish and invertebrates all threaten the survival of the salt marsh. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Physical structures in the upland: Any structure that dams or alters freshwater input from the mainland into a salt marsh ecosystem negatively impacts salt marsh production and success.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.

- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect the salt marsh. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Impoundment of water: Impoundments smother intertidal species and kill marsh plants.
- Invasion of opportunistic plants and animals: Physical alterations of salt marshes can weaken marsh systems and encourage the invasion of exotic and pest plants (e.g. purple loosestrife, common reed (*Phragmites*)) and animals (e.g. rats).

What are the Permitting Issues of Salt Marsh?

- Avoid all activity in, on, over or adjacent to the salt marsh.
- Especially avoid permitting activities that fill, shade, dredge, ditch, or drain the salt marsh. No sediment disposal should be permitted in or adjacent to the salt marsh.
- Water dependent structures (e.g. walkways, piers) should be placed in areas that will not shade the salt marsh in the winter or the summer. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see guidelines for eelgrass). Don't permit any structure that will lie on the salt marsh. Encourage the joint use of public piers instead of the creation of a new structure.
- For lobster pounds, restrict any activity or impoundment from within at least 25 feet (distance recommendation by NMFS) of the salt marsh.
- Discharges of freshwater or pollutants should be minimized in or around the salt marsh.
- Large machinery should not be allowed on salt marshes.
- Physical barriers should only be permitted in emergency situations. Barriers should minimize the restriction or alterations of current, fresh water, and tidal flows.
- Ditching of salt marshes should not be permitted. Animal travel corridors should not be altered. Sediment movement should not be restricted or enhanced. Human activity and disturbance should be minimized.
- Coastal development on the upland should be restricted. Plan for future sea level rise and allow for ample landward migration of the salt marsh.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on salt marshes should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Salt Marsh (adapted from Short, F.T. et al. 1999).

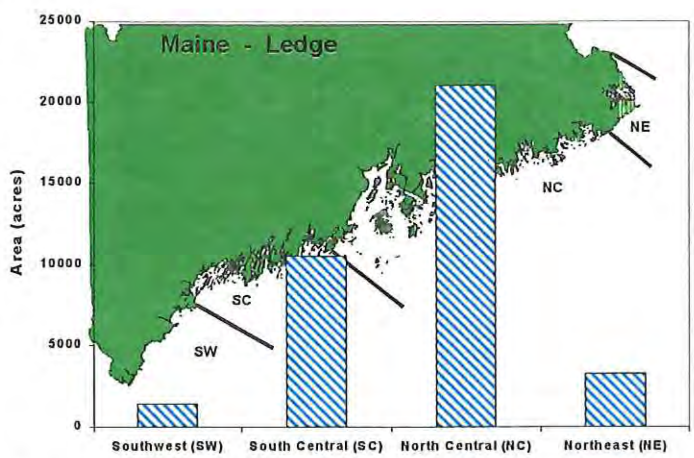
Functions	Values
1. Primary production and seed production	Supports food webs Supports fisheries and wildlife Creates a habitat with high biodiversity
2. Three dimensional canopy structure	Creates habitat Refuge from predation and weather Nursery and larval and egg settlement Supports commercial fisheries
3. Production , accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries Reduces storm surge and slows shoreline erosion
4. Sediment sink and trap	Improves water quality Supports fishery Lessens coastal erosion
5. Secondary production	Support of food webs Supports commercial fisheries and wildlife Supports terrestrial mammals and birds, waterfowl, wading birds and shorebirds
6. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
7. Rare plant and animal habitat	Supports endangered species of Piping plover Supports endangered and threaten plant species
8. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
9. Dampens current and wave energy	Prevents upland erosion Minimizes flood damage Reduces resuspension of sediments Increases sedimentation
10. Self-sustaining ecosystem	Encourages recreational and educational activities High aesthetic value / attracts tourists Landscape level biodiversity

Functions and Values of Ledge:

What is Ledge?

Intertidal ledge is bedrock that is exposed to ocean waves, tidal currents, ice, rain and solar radiation. Ancient ledge is either volcanic rock or metamorphic rock, a softer rock scoured out by past glaciations and prone to slow erosion by waves or weathering (Kelley et al. 1989). Granitic headlands, resistant to erosion, form the edge of the eastern seaboard and protect beaches and estuaries from severe ocean swells. Bedrock is a stable permanent structure that allows intertidal plants and animals to attach and colonize substrates. Ledge features approximately four zones of plants and animals tolerant of different levels of predation pressure, tidal exposure and other physical and biological factors. The high intertidal zone, barnacle zone, rockweed zone, and Irish moss zone are usually present on exposed shores. Bedrock contains depressions, cracks and crevices that create tidepools and sheltered habitats as the tide recedes from the shore. Some ledge habitats have boulders at their base.

Where is Ledge Located in Maine?



Ledge is the second most common intertidal habitat in Maine. There are 36,243 acres of rock ledge on the coastline of Maine. Thirty-five percent of this habitat is on offshore islands. A majority of the ledge habitat is located in the central and eastern portions of the state. Only 4 % of rocky shores is found south of Cape Elizabeth. Almost 60 % of the ledge in Maine is located in the "island-bay complex" (Kelley et al. 1989) between Penobscot Bay and Machias Bay.

What are the Functions of Ledge?

Ledge habitats have different ecological functions based on their exposure to wave energy and their location within the intertidal zone. Ledge supports populations of animals specially adapted to survive battering by high energy surf. In general, exposed sites have the greatest bio-diversity of macroalgae and invertebrates. Yet, sites that are too exposed to pounding surf have fewer species due to damage and removal of organisms by powerful waves. Diversity and productivity on rocky shores increases as you move from the high intertidal to the subtidal.

Rocky shores are one of the most diverse and productive intertidal habitats (USF&W 1980 Ch 4). Rocky shores support populations of suspension feeders (e.g.mussels, barnacles, sponges), grazers and herbivores (e.g. sea urchins, limpets, snails), predators (e.g. rock crabs, dog winkles, blood stars, sea stars, nudibranchs), carnivores (e.g. anemones) and scavangers (e.g. amphipods). Ledges are attachment sites for rockweeds, kelps, other macroalgae and Irish moss (see kelp and rockweed). Irish moss provides attachment sites for plants and animals; primary food for invertebrates and fish; shelter for marine life from wave and wind exposure, temperature extremes, ice scour, dessication, and other physical factors; and nursery areas for invertebrates and fish. Tidepools, within basins of the ledge, offer a refuge from extremes in temperature and salinity for a rich assemblage of plants, invertebrates and fish. Tidepools provide habitat for brittlestars, amphipods, scaleworms, sea urchins, arctic clams, chitons, limpets, sea stars, snails, lumpfish, rock gunnel, sticklebacks, sculpins, seasnails, grubby, cunners, anemones, sponges, hermit crabs, nudibrachs, tunicates, and worms (Brown 1993). Downeast spider crabs and sea spiders are found living in tide pools. Crevices and cracks in the bedrock are settled by numerous species that can only survive in sheltered habitats.

Sea-birds (e.g. oldsquaw, common eider, black scoter), loons, herring and black-backed gulls, at least 9 species of shorebirds, waterfowl, cormorants, osprey and ducks (e.g. mergansers, loons, golden-eyes, harlequin ducks) prey on snails, mussels, fish, amphipods and other invertebrates on rocky shores (Mathieson et al. 1991; Brown 1993; USF&W 1980). Ledges are foraging sites for mink and terrestrial birds. Bedrock on outer islands of Casco Bay provide wintering habitats for scoters, eiders and old squaw ducks and are utilized by brant in the spring (USF&W 1980).

Ledge functions as roosting habitat during seasonal migrations for 14 species of shorebirds (USF&W 1980).

Ledges surrounding islands and isolated mainland headlands are foraging habitats and haulout, breeding, and pupping sites for gray and harbor seals (USF&W 1980).

Upper shores of ledge habitats with sediment deposits support populations of rare plants (USF&W 1980).

Bald eagles and ospreys nest and feed near ledge habitats (Brown 1993).

Ledges are wintering habitat for purple sandpipers (USF&W 1980).

What are the Economic and Recreational Values of Ledge?

Ledges function as a nursery area, foraging habitat and attachment site for commercial species of invertebrates and fish valued at over $164 million in 1997 (NOAA 1997). It is an important settling, nursery and foraging area for lobsters, sea urchins, blue mussels, and periwinkles. Juvenile pollock, in the summer time, feed during high tide day and night on amphipods, periwinkles, mussels and isopods on vegetated rocky shores (Rangeley and Kramer 1995). Kelp, rockweed, Irish moss and dulse are harvested from rocky shores. Rock gunnel and other small fish live on ledge and feed adult cod and pollock. Tidepools are used as foraging areas during high tide by winter flounder and pollock (Brown 1993).

Rocky shores are foraging areas for striped bass, an important recreational fishery in Maine.

How Sensitive is Ledge to Disturbance and Development?

Ledge habitats have three levels of DEP classifications based on their location in the intertidal zone (see Habitat Rankings). Low intertidal zones of ledge with algae are classified as highly sensitive to disturbance because they are very diverse productive habitats supporting populations of algae and animals restricted to this environment. Low intertidal species can not tolerate disturbance, salinity changes, desiccation, or pollution. Mid-intertidal zones with algae are classified as moderately sensitive to disturbance. Mid and high intertidal zones without algae are inhospitable environments and are therefore classified as low sensitivity habitats.

What are the Threats to Ledge?

- Shading from physical structures: Shading blocks light and reduces algal growth.
- Removal of habitat: Blasting of ledge or placement of structures removes habitat and animal communities.
- Pollution: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and others all damage ledge communities.
- Resuspension of sediments: Resuspention of sediments from nearby dredging, filling, boating and fishing activity smother animals on ledge.

What are the Permitting Issues of Ledge?

- Avoid permitting activities that remove habitat and/or threaten algal or marsh communities on ledge.
- Permit activities in mid and high intertidal zones without vegetation; avoid any activity in low intertidal or shallow subtidal zones.
- Water dependent structures should be place in areas that will not shade algae or indirectly impact algal beds on ledge. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade or scour beds.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around ledge habitats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Intertidal Ledge Habitats.

Functions	Values
1. Production of animals on rocks, in tide pools, on and within algal beds	Supports commercial fisheries Supports the food web Supports recreational sport fishery Support shorebirds, seabirds, and sea ducks Support terrestrial mammals Supports bald eagles, osprey and harbor seals
2. Permanent and stable attachment sites for primary producers (see kelp / rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Roosting sites and wintering habitat for birds and haulouts for mammals	Helps sustain healthy populations of shorebirds, sea birds, sea ducks, brant, gray and harbor seals
4. Intercepts and slows currents and waves	Reduces shoreline erosion of nearshore habitats Increases sedimentation Enables formation of protected soft bottom habitats
5. Nursery and spawning ground	Helps sustains commercial fishery populations Maintains balanced ecosystem
6. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
7. Rare plant and animal habitat	Supports bald eagles Supports rare plant species on upper ledges
8. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
9. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
10. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
11. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats Supports movie and tourism industry

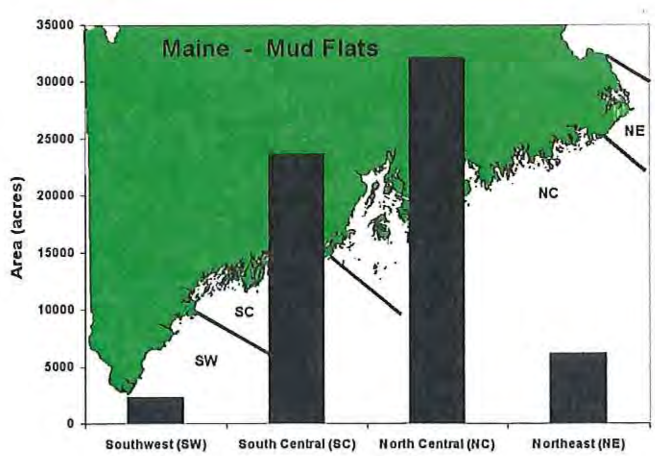
Functions and Values of Mud Flats:

What are Mud Flats?

Intertidal mud flats are low energy protected environments that are ecologically and commercially important habitats in Maine. Sediments are composed of fine clays, silt, sand and organic matter. Sediments are supplied to the mud flat from the terrestrial environment by rivers and streams, landslides and adjacent eroding coastal bluffs and margins of bays (Kelley et al. 1989). Sediments are constantly redistributed by tidal action and wind generated waves and currents. Anoxic sediments, black colored mud depleted in oxygen, usually are present below the surface (1/2 - 2 cm depending on total organic carbon). Gray colored sediments below anoxic sediments indicate the presence of iron pyrite (Whitlatch 1982)

Where are Mud Flats Located in Maine?

In Maine, there are approximately 64,300 acres of mud flats totaling 44 % of all coastal intertidal environments. They predominately occur in protected bays, coves, inlets and estuaries. The majority is north of South Portland, with the highest concentration (60 %) located north of Port Clyde. Only 4 % of all mud flats in Maine is found south of Cape Elizabeth.



What are the Functions of Mud Flats?

Mud flats are organically rich regions that support large populations of shellfish, shrimp, mussels, quahogs, baitworms, and small invertebrates (Larson and Doggett 1991). By slowing tidal and wave energy, mud flats buffer the upland against tidal erosion and lessen impacts from storm surge events. Eelgrass beds and macroalgae, that add structure to the habitat, cover many flats in Maine (see photo). Sediments contain high concentrations of benthic diatoms that form the base of the benthic food web, remove nutrients from the mud, and lessen erosion by binding sediments. Small fish like mummichogs and sticklebacks forage on invertebrates and algae during flood and ebb tide (Whitlatch 1982). Flats support high concentrations of bacteria, fungi, and other microorganisms that contribute to nutrient cycling and provide food for larger macrofauna like sand worms. They are limited resources that perform a vital function as sinks for contaminants.

Mud flats are critical feeding grounds for 25 species of migrating and resident shorebirds, six species of herons, two species of egrets, glossy ibis, Canada geese, commercial and non-commercial finfish, herring gulls and waterfowl (USF&W 1980). Flats are nursery grounds for winter flounder and other flatfish. They provided roosting and staging areas for migrating shorebirds (USF&W 1980; Larsen and Doggett 1991).

Mud flats are potential habitat for the rare plant pipewort (*Eriocaulon parkeri*)(USF&W 1980).

What are the Economic Values of Mud Flats?

Mud flats contribute to a multi-million dollar seafood industry in Maine by providing structure and foraging habitat for soft-shell clams, Atlantic herring, blood worms, blue mussels, sand worms, periwinkles, alewife, winter flounder, rainbow smelt, Atlantic mackerel and sand shrimp (Brown 1993; Whitlatch 1982).

How Sensitive are Mud Flats to Disturbance and Development?

Mud flats are low energy protected and productive environments that are classified by DEP as highly sensitive to anthropogenic influence (see Habitat Rankings). They are the most sensitive marine habitat to perturbations (Larsen and Doggett 1981). Mud flats are protected from heavy wave and current action. Therefore, flushing is limited, causing flats to recover slowly from physical disturbances and pollutants to concentrate. Contaminants can accumulate in the fine sand and clay particles, building up to toxic levels.

What are the Threats to Mud Flats?

- <u>Filling of mud flats:</u> Filling results in a direct loss of intertidal habitat.
- <u>Dredging, dragging or other major physical disturbances</u>: Disturbances liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion. Dragging kills epifauna and encourages the spread of opportunistic species.
- <u>Sediment disposal:</u> Disposal of any sediments or other material smothers plant and animal life.
- <u>Seawalls and other shoreline stabilization barriers (e.g. riprap):</u> Mud flats require continual sources of sediments from upland and coastal erosion. Without renewable

resources of fine grain sediments entering these regions, surface layers of mud flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. As sea levels rise, physical barriers prevent the intertidal region from extending landward thus decreasing the acreage of intertidal habitat.

- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect mud flats. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Lobster pound creation / Impoundment of water: Lobster pounds convert intertidal areas into subtidal areas by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and a reduction in species diversity within the benthic and algal communities.
- Other physical barriers: Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of flats, prevent sediment movement and larval and fish passage threaten the survival of mud flats.
- Pipe laying: Laying of pipe leads to the loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Mud Flats?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around mud flats. No filling of flats should be permitted without proper compensation. Large machinery should not be allowed on mud flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of mud flats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on mud flats should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Mud Flats (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Production of animals on and within the mud or sand	Supports commercial fisheries Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion / resuspension Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercially important fish Roosting and staging areas for migrating shorebirds

Shallow Subtidal Habitats

Functions and Values of Subtidal Unconsolidated Sediments:

What are Sudtidal Unconsolidated Sediments?

Unconsolidated bottoms are subtidal extensions of intertidal fine grained flats. Like intertidal flats, sediments are composed of fine clays, silt, mud, sand, gravel and organic matter. They receive replenishment of sediments from the same terrestrial sources as intertidal flats. Subtidal unconsolidated sediments occur in the same areas as intertidal flats but extend far offshore. Some intertidal ledge habitats and boulder beaches blend into unconsolidated sediments in the subtidal.

What are the Functions of Subtidal Unconsolidated Sediments?

Subtidal shallow sandy regions have many similar functions to intertidal mud flats but they are a more diverse and productive habitat. Shallow subtidal soft bottom communities in Portland Harbor support as many as 120 - 36,380 animals / m^2 (Larsen, Johnson, and Doggett 1983). Benthic sediments are homes to billions of microscopic diatoms and bacteria. Diatoms, single-celled algae, convert nutrients into organic matter, oxygenate the sediments and provide food for herbivores. Bacteria feed sediment deposit-feeders and break down organic matter releasing nutrients back into the water column. Animals that contribute to the ecological health of the subtidal community include, horseshoe, hermit and mud crabs, polychaete and oligochaete worms, amphipods, isopods, snails, bivalves, mysid and sand shrimp, brittle and sea stars, sea pens, cumaceans, sand dollars, threespined stickleback, mummichug, alligator fish, rock gunnels, longhorn sculpin, lumpfish, anemones, cusk, hagfish, tautog, redfish, wolffish, cunner, shannies, rocklings, grubbies, rock eels and flounder (Larsen, Johnson and Doggett 1983; Brown 1993; USF&W 1980; Wippelhauser et al. 1997). Eelgrass frequently covers shallow zones adding to the structure and productivity of shallow subtidal regions. Sandlance, an extremely important food resource for fish, mammals and birds, inhabit sandy sediments inshore to the continental shelf (USF&W 1980).

The sublittoral fringe, a narrow zone from the low intertidal to – 5 meters below mean low water, has a high diversity and abundance of invertebrates, high benthic chlorophyll and a reduced number of grazers. Thousands of shrimp and amphipods take refuge here as the tide recedes. The zone is a nursery area for mysid shrimp, amphipods, wrymouth and other marine animals. This region is known to support populations of priapulid worms, quahogs, clams, and oysters (Les Watling, personal communication).

What are the Economic Values of Subtidal Unconsolidated Sediments?

Subtidal unconsolidated bottoms are feeding, spawning, and nursery grounds for commercial species of fish and invertebrates. Sediments contribute to the development of a commercial fishery valued at over $ 200 million in 1997 (NOAA 1997). Juvenile lobsters create subtidal muddy burrows for shelter from predators and establish feeding territories. Additional fisheries include sea urchins, Northern pink shrimp, scallops, blue mussels, rock crabs, sand worms, periwinkles, quahogs, sea cucumbers, black clams and waved whelks (Brown 1993; USF&W 1980). Subtidal fine sediments also support populations of Atlantic herring, American plaice, Atlantic cod, witch flounder, white hake, skate, alewife, winter flounder, yellow flounder, and rainbow smelt (Whipplehauser et al. 1997; USF&W 1980; Stevenson and Knowles 1988).

How Sensitive are Unconsolidated Sediments to Disturbance and Development?

Productive and diverse subtidal unconsolidated sediments, especially shallow subtidal, are classified by DEP as highly sensitive to disturbance and development (see Habitat Rankings). These regions contain a high diversity of animals that are restricted to subtidal areas and can not tolerate great fluctuations in temperature, salinity, and physical disturbance.

What are the Threats to Subtidal Unconsolidated Sediments?

- Dredging, dragging or other major physical disturbances: Dredging results in the loss of productive subtidal habitats. Major dredging operations may cause erosion of intertidal and salt marsh habitats. Physical disturbances liberate toxics and nutrients from unconsolidated sediments into the water column and harm plant and animal communities.
- Dredging disposal: Disposal of sediments smother animal and plant life resulting in the direct loss of species diversity.
- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect subtidal communities. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Physical structures: Physical structures threaten subtidal environments directly and indirectly. Structures replace productive fine sediments with less valuable hard structures. They can shade shallow habitats, change current or tidal flows or directions, alter salinity, prevent sediment movement and block larval and fish passage.
- Mining for sand and gravel: Mining results in the loss of subtidal habitat.
- Trenching: Building trenches for utilities lines temporarily disturbs subtidal habitats.

What are the Permitting Issues of Subtidal Unconsolidated Sediments?

- No physical structures or fill should be permitted in subtidal environments. Filling may violate Maine's water quality laws (see Maine's Water Classification Act) or smother productive habitats. Any activity that would disturb shallow subtidal communities, alter sediment type, or shade subtidal habitats, especially in the sublittoral fringe, should be avoided.
- Temporary impacts to subtidal communities, as in the case of dredging and trenching, may be permitted as long as the sediment type will not be changed and the community can be expected to return to its original condition within a few years time.
- Dredging should be avoided or managed in a careful manner by conducting chemical sediment core analysis before permitting any activity.

Summary of the Functions and Values of Subtidal Unconsolidated Sediments.

Functions	**Values**
1. Production of animals on and within the sediment	Supports lobster, finfish and urchin fishery Foraging habitat for forage fish and top consumers Supports the food web Increases marine biodiversity
2. Primary production from benthic diatoms, algae and eelgrass	Improves water quality Binds sediments therefore reducing erosion Oxygenates sediments and water column Fuels benthic food web Supports commercial fisheries and wildlife
3. Nursery and spawning ground	Promotes growth and existence of species (commercial and ecologically important) Supports the food web and ecosystem health
4. Recycling of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries Maintains a balanced marine ecosystem
5. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
6. Refuge during low tide	Protects species from predation and the atmosphere
7. Essential habitat	Provides the soil for eelgrass germination and proliferation Feeds subtidal community

Functions and Values of Subtidal Mixed Coarse:

What is Subtidal Mixed Coarse?

Subtidal mixed coarse is shallow habitats comprised of cobble, gravel and boulders. These habitats are never exposed to the atmosphere. The wave energy is moderate to high. Cobbles are rocks ranging between 2.5 - 10 inches in diameter. The surf can overturn the smaller rocks. Boulders are 1-10 ft in diameter. Mixed coarse habitats dominated by boulder fields are stable habitats. Boulders can not be overturned by waves except by extremely powerful storms. Gravel are small rocks (1-2.5 inches in diameter) that are constantly shifting in the surf. Little information is known about the ecology of subtidal cobble, gravel and boulder habitats. Rocks, especially larger boulders, may be covered by numerous species of macroalgae.

Where is Subtidal Mixed Coarse?

Mixed habitats are often located seaward of moderate and high energy intertidal ledge, boulder, cobble and gravel habitats. Cobble habitats make up only 2- 10 % of the shallow subtidal habitat in Maine (Brown 1993).

What Are the Functions of Subtidal Mixed Coarse?

Mixed coarse habitats have similar functions as intertidal mixed coarse and boulder fields. However, since they are never uncovered by salt water and exposed to the conditions on land they support a greater diversity of algae and animals. Shallow subtidal habitats contain as many as 60 species of macroinvertebrates (Ojeda and Dearborn 1989). Mixed coarse habitats dominated by boulders and cobble create shelter and foraging habitat for lobsters, sea stars, green crabs, shrimp, polychaete worms, sponges, sea anemones, barnacles, hermit crabs, chitons, brittle stars, snails, sea squirts, sea spiders, amphipods, isopods, flat worms and others. Clumps of blue mussels and horse mussels, a dominate subtidal species, create a stable microhabitat for sensitive species within its byssus threads. Threads collect food particles and slow currents allowing species to forage optimally. Coraline algae cover boulders and are grazed upon by snails and urchins (Ojeda and Dearborn 1989). Small fish like the rock gunnel, sea snail, snakeblenny, tautog, and radiated shanny inhabit boulder and cobble bottoms feeding on the abundant marine life (USF&W 1980). Macroalgae cover shallow habitats. Expansive kelp beds increase the functions and values of mixed habitats (see Kelp beds). Boulders break wave energy and slow shoreline erosion.

The alga known as *Leptophytum laeve* is only found within this habitat.

What Are the Economic Values of Subtidal Mixed Coarse?

Mixed coarse sediments supported fisheries landed and valued at over $178 million in 1997 (NOAA 1997). Mixed subtidal habitats are inhabited by commercial species of sea urchins, blue mussels, periwinkles, sand shrimp, sea cucumbers, soft-shell clams, winter flounder, American eel, American lobster and sea raven (USF&W 1980). Kelp and Irish moss may be harvested from these habitats.

Subtidal vegetated and unvegetated unconsolidated coarse sediments are nursery grounds for the "early benthic phase" of the American lobster and rock crabs. Lobster and crab larvae metamorphose into juveniles and move inshore settling out of the plankton and onto the benthos. The cobble-boulder habitat provides shelter and foraging areas for juvenile lobsters. Lobster settlement occurs between August and September (Wahle and Steneck 1991).

How Sensitive Are Subtidal Mixed Coarse to Disturbance and Development?

Mixed coarse subtidal habitats are classified by DEP as highly sensitivity habitats (see Habitat Rankings). They contain diverse assemblages of species nonresistant to perturbations. Mixed coarse habitats are an essential rare habitat that provide protective cover for young settling American lobsters on the outer coast from shallow subtidal to 30 m depth (Wahle and Steneck 1991). Without the protective nature of the habitat, juvenile lobsters, less than ½" in length, would be subject to high mortality from fish and other predators. These specialized habitats are limited in Maine and may limit benthic recruitment of lobsters if the environments are threatened (Wahle and Steneck 1991).

What Are the Threats to Subtidal Mixed Coarse?

- <u>Shading from physical structures</u>: Shading blocks light and reduces growth of algae.
- <u>Removal and/ or disturbance of habitat</u>: Dredging, removal of boulders, scouring by boat traffic, dragging by fisherman, and sediment loading smothers habitat.
- <u>Pollution</u>: Run-off of sediments and pollutants from upland construction sites and parking lots, increases in freshwater discharge, industrial discharges, chlorinated effluent, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and others damage subtidal habitats.
- <u>Resuspension of sediments</u>: Resuspension of sediments from dredging, filling, boating and fishing activity smothers habitat. Resuspension of sediments may resuspend larvae and small invertebrates changing the community structure of the habitat and endangering animals and algae.
- <u>Other physical barriers:</u> Any structures (e.g. groin, dam, bridge) that can change current or tidal flows or directions, alter salinity, prevent sediment movement and larval and fish passage threaten the survival of subtidal cobble, gravel and boulder habitats.

- Trenching: Building trenches for utilities lines temporarily disturbs subtidal habitats.

What are the Permitting Issues of Subtidal Mixed Coarse?

- Avoid permitting any activities in cobble, gravel and boulder habitats.
- Avoid permitting any activities that remove algal communities.
- Water dependent structures should be place in areas that will not shade algae or indirectly impact algal beds. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade or scour beds.
- Survey areas for lobsters. Lobsters may concentrate in kelp beds or under boulders and cobbles.
- Avoid sediment disposal on or around subtidal mixed coarse habitats. Avoid activities that will resuspend sediments around habitats.
- Dredging should be avoided or managed in a careful manner by conducting chemical sediment core analysis and functional assessments before permitting any activity.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Physical barriers should only be permitted in emergency situations.
- Discharges of freshwater or pollutants should be minimized around subtidal habitats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.

Summary of the Functions and Values of Subtidal Mixed Coarse.

Functions	Values
1. Production of animals on boulders, under cobbles, within sediments and on and within algal beds	Supports commercial fishery Supports the food web Supports recreational sport fishery Supports shorebirds, seabirds, seaducks and waterfowl Supports gray and harbor seals
2. Attachment sites for primary producers (see kelp / rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Slows currents and waves	Reduces shoreline erosion Increases sedimentation
4. Nursery and spawning ground	Helps sustains commercial fishery populations Rare nursery habitat for lobsters Maintains balanced ecosystem
5. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
6. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
7. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
8. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
9. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats

Functions and Values of Subtidal Ledge:

What is Subtidal Ledge?

Subtidal ledge is stable bedrock habitats that are never exposed to the atmosphere during low tides. Subtidal ledge contains cracks, crevices, vertical walls and overhangs. Many habitats are located in high energy regions exposed to pounding ocean swells. Ledge habitats slope to the seafloor and often blend into boulder fields or soft unconsolidated bottoms. Algae and animals colonize free space on the ledge and often form multiple layers of organic material. In cold winters, ice can scour the ledge in sheltered areas removing all layers of plant and animal growth.

Where is Subtidal Ledge Located in Maine?

Subtidal ledge is located off rocky shores on the mainland and offshore islands of Maine. Intertidal ledge extends offshore creating subtidal bedrock features (see intertidal ledge for distribution). Additional ledge habitat is found on offshore rock pinnacles in the Gulf of Maine and near Mt. Desert.

What are the Functions of Subtidal Ledge?

Subtidal ledges have similar functions to low intertidal ledge habitats but they have a greater diversity of algae and animals and complexity of horizontal and vertical communities. Diatom mats cover ledge and feed herbivorous gastropods. Kelp beds, red and green algae, and horse mussel communities create three-dimensional structures, trap sediments and provide spatial refuges that result in a high diversity of marine species including sea urchins, shrimp, worms, herbivorous amphipods, sea cucumbers, snails, sea stars, limpets, nudibranchs, chitons, hermit crabs, spider crabs and other aquatic organisms. Sessile suspension-feeding animals (e.g. sponges, polychaete tube worms, tunicates) and predatory animals (e.g. anemones) layer on top of coralline algae and also trap sediments creating additional complex communities of infauna species like bivalves, brittle stars, and worms below surface waters. Mats of amphipods live within canopies of red algae. Cracks and crevices provide spatial refuges from predation for invertebrates and fish (Ojeda and Dearborn 1989; Mathieson et al.1991).

At shallow depths, seabirds, loons, eider ducks, goldeneyes, mergansers, harlequin ducks, oldsquaw, scoters, herring gulls, and grebes feed on subtidal invertebrates (Mathieson et al.1991; USF&W 1980).

Numerous small fish that feed top predators seek shelter and forage within this environment. Sea raven, eelpout, wrasse, radiated shannies, rock gunnel, ocean pout, cunner, snake blenny, sculpins, smelt, grubby, lumpfish, rocklings, rock eels, tautogs, cusks, and goosefish inhabit this zone (Brown 1993; Ojeda and Dearborn 1989, 1991; Factor 1995).

Ledge intercepts open ocean generated waves, breaks wave energy and decreases shoreline erosion.

What are the Economic and Recreational Values of Subtidal Ledge?

Subtidal ledge supports at least twenty-nine commercial species in Maine landed and valued at over $175 million in 1997 (NOAA 1997). Rock crab, Jonah crabs, sand shrimp, green sea urchin, sea cucumber, blue mussel, oyster, horse mussel, periwinkle, and whelks settle, feed and seek shelter in ledge environments (Brown 1993; Ojeda and Dearborn 1989, 1991). Lobsters occupy the edges of kelp beds for shelter and foraging (Bologna and Steneck 1993). American eel, haddock, redfish, wolffish, yellowtail flounder, winter flounder, spiny dogfish, mackerel, sea raven, pollock, Atlantic herring, Atlantic cod, American shad, silver hake, bluefish, cunner, and skate forage in subtidal ledges (Brown 1993; Ojeda and Dearborn 1989, 1991; Mathieson et al.1991). Kelp and Irish moss are directly harvested from subtidal ledges on the mainland and offshore islands.

Vegetated off-shore rock pinnacles are used as substratum for the deposition of Atlantic herring eggs. These habitats are believed to reduce larval mortality of fish (Mathieson et al. 1991).

Striped bass, one of the most important coastal recreational fisheries in Maine, live and forage within subtidal ledge habitats (USF&W 1980).

How Sensitive are They to Disturbance and Development?

Subtidal ledge environments are a multi-functional productive habitat that has been classified by DEP as having a high sensitivity to disturbance and development (see Habitat Rankings). Subtidal ledge environments contain unique species that cannot resist perturbations or adapt readily to other habitats.

What are the Threats to Subtidal Ledge?

- Shading from physical structures: Shading blocks light and reduces algal growth.
- Removal of habitat: Blasting of ledge removes habitat and animal communities.
- Fill: Filling of habitat smothers algae and animals and reduces attachment sites.
- Pollution: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and others all damage subtidal ledge communities.
- Resuspension of sediments: Resuspension of sediments from nearby dredging, filling, boating and fishing activity smother animals on ledge.
- Dragging: Dragging by fisherman removes kelp and invertebrates and reduces shelter.

What are the Permitting Issues of Subtidal Ledge?

- Avoid permitting <u>any activity</u> in subtidal ledge environments.
- Avoid permitting activities that remove, disturb or change habitat structure.
- Water dependent structures should be place in areas that will not shade subtidal ledge communities. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can affect algae and organisms.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around ledge habitats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Subtidal Ledge.

Functions	**Values**
1. Production of animals on rocks, in cracks and crevices, on and within algal beds	Supports commercial fishery Supports the food web Supports recreational sport fishery Supports shorebirds, seabirds, seaducks and waterfowl Supports gray and harbor seals
2. Permanent and stable attachment sites for primary producers such as diatoms, kelp, red algae and rockweed. (see kelp/rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Slows currents and waves	Reduces shoreline erosion Increases sedimentation
4. Nursery and spawning ground	Helps sustain commercial fishery populations Maintains balanced ecosystem
5. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
6. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
7. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
8. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
9. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats

Vegetated Habitats

Functions and Values of Rockweeds:

What are Rockweeds?

Rockweeds are brown macroalgae such as *Ascophyllum spp.* and *Fucus spp.* Like kelps, they are primary producers converting inorganic nutrients into organic biomass by using the energy of the sun. They lack true roots, stems and leaves and because they lack a vascular system, absorb dissolved nutrients directly through the blades. The holdfast is used to attach the algae to intertidal rocks. Without attachment to hard substrates, algae will die. Unlike kelp, rockweeds have a higher light requirement, a higher water temperature tolerance (0 - 28°C), a higher tolerance to low salinity waters and, to some degree, can resist desiccation, ultraviolet radiation and overheating. Rockweeds can grow vegetatively or sexually. For *Fucus spp.* sexual reproduction can occur year-round while *Ascophyllum nodosum* reproduces in the late spring and early summer. In Maine, the life span of rockweeds ranges from approximately three years of age for *Fucus vesiculosus* to 16 years for *Ascophyllum nodosum* (Wippelhauser 1996). They grow slowly, therefore the recovery period for damaged or uprooted rockweeds can be decades.

Where are Rockweeds Located in Maine?

Rockweeds inhabit all intertidal zones with rocky substrates and seldom populate shallow subtidal habitats. They are the dominant algae in Maine, commonly found on rocky shores statewide. Rockweeds are located on sheltered and high energy ledge, boulder, and mixed course intertidal habitats. Small clumps can be found on sand flats or mud flats attached to rocks.

What are the Functions of Rockweeds?

Rockweeds are primary producers converting inorganic (e.g. phosphate and nitrate) nutrients into organic matter for grazers. They play an essential role in removing inorganic nutrients and trace metals and converting them into usable products for commercial and ecological use. By removing nutrients and metals (e.g. arsenic, copper, zinc) from the water column they help maintain water quality in bays, estuaries and rocky shores. Like eelgrass and kelp, portions of the algae break apart and are transported by tides and currents to the nearshore forming large deposits of organic detritus. This detritus forms one of the bases of estuarine and marine food webs. The detritus formed from the dead algal matter is consumed by bacteria, and small marine invertebrates and insects which, in turn, feed birds, fish and mammals. Algal fragments also are carried offshore and feed the diverse subtidal benthos. Rockweed beds add structural complexity and surface area to rocky habitats. During low tides when the shores are exposed to air and direct sunlight, rockweeds provided protection to inhabitants from temperature fluctuations and desiccation. They provide shelter from predation and wave action, attachment sites for epiphytes and larvae, food resources for invertebrates and fish, feeding and nursery grounds for crustaceans (Wippelhauser 1996).

What are the Economic Values of Rockweeds?

Rockweeds have both indirect and direct commercial values in Maine. Approximately 4,000,000 - 7,000,000 pounds of rockweed are harvested annually in Maine (Fried 1999). Rockweeds are commercially harvested and sold as health food, nutritional supplements for humans and pets, fertilizer, agricultural products and packing material for lobsters. Rockweed is used as a stabilizer in food and cosmetics.

Indirectly, rockweeds support recreational and commercial fisheries by providing shelter for lobsters, foraging for juvenile fish, and food for herbivores, the prey of fish, waterfowl, and crustaceans. Juvenile pollock, in the summer feed during high tide on intertidal amphipods, periwinkles, mussels and isopods living on and within rockweed (Rangeley and Kramer 1995). Common periwinkles and sea urchins, worth $20 million at the dock in 1997, feed on rockweed in the shallow subtidal (NOAA 1997). Juvenile lobsters, supporting a fishery valued at over $138 million upon landing in 1997 (NOAA 1997), settle, forage and seek refuge in low intertidal rocky habitats covered in rockweed.

How Sensitive are Rockweeds to Disturbance and Development?

Rockweed habitats have been classified by DEP as moderately sensitive to disturbance and development in Maine (see Habitat Ranking). Even though they are ecologically and commercially essential habitats, they are widely distributed and have fewer functions and values than high sensitivity habitats. Due to their ability to resist the severe conditions of the exposed mid intertidal environment, the algae are less susceptible to disturbance.

What are the Threats to Rockweed Communities?

- <u>Shading from physical structures</u>: Shading blocks light and reduces growth.
- <u>Removal and/ or disturbance of habitat</u>: Dredging, filling, blasting of ledges, removal of boulders, impoundment of water, sediment loading and over-turning of rocks displaces, smothers or removes rockweed and its habitat.
- <u>Resuspension of sediments</u>: Resuspension of sediments from dredging, filling, boating and fishing activity smother rockweed.
- <u>Pollution</u>: Run-off of sediments and pollutants from upland construction sites, thermal discharges, industrial discharges, chlorinated effluent, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and other activities all damage rockweed. In addition, phytoplankton blooms caused by nutrient loading from pollution cause reductions in light levels harming rockweed communities.

- Over-harvesting

How Should Rockweed Habitats be Managed?

- Avoid permitting activities that remove rockweed and rockweed habitat.
- Water dependent structures should be placed in areas that will not shade rockweed. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines).
- Avoid sediment disposal on or around rockweed.
- If applicable, determine if current velocity, tidal flows or wave energy will be altered due to the proposed activity. If so, design the project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around rockweed.
- New developments in the upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.

Summary of the Functions and Values of Rockweeds.

Functions	Values
1. Primary production	Food for invertebrates and fish Support commercial fisheries and wildlife Commercially harvested for food and nutrients
2. Three dimensional canopy structure	Create habitat in barren environments Refuge from predation, wave action, solar radiation, desiccation, weather, and temperature extremes Nursery for invertebrates and lobsters (low zones) Attachment site for larvae and eggs Increases biodiversity Supports commercial fisheries
3. Increases secondary production	Supports the food web Supports commercial fisheries
4. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
5. Dampens current and wave energy	Reduces shoreline erosion Increases sedimentation
6. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
7. Structure for the attachment of algae, diatoms and animals	Food resources for consumers Increases primary production Supports commercial fisheries
8. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
9. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries

Functions and Values of Eelgrass (*Zostera marina*)

What is Eelgrass?

Unlike algae, eelgrass is a vascular flowering plant with roots, stems and leaves. Eelgrass is an annual and perennial plant. The perennial spreads through sexual reproduction and asexual vegetative growth but the annual reproduces sexually (Keddy 1987). The annuals over winter as seeds (Robertson and Mann 1984). In some regions perennial plants function as annuals. Both annuals and perennials have equally valuable functions (Fred Short, personal communication, April 1998). The annuals produce a greater amount of flowers and seeds per unit area than the perennial plants (Keddy 1987). Eelgrass is intolerant of severe desiccation. Eelgrass tolerates a wide salinity and temperature range but is limited by light. Plant biomass is greatest in the summer months and decreases in winter. Ice scour uproots eelgrass in shallow intertidal regions in the winter (Wippelhauser 1996). Perennial beds can live for more than 10 years (Beal 1994).

Where is Eelgrass Located in Maine?

Eelgrass is located statewide in low intertidal and shallow subtidal mud flats, sand flats, and mixed course and fines environments in protected coves, bays, inlets and shallow tidal rivers. Eelgrass is limited by light availability but is known to survive to 35 feet deep (Wippelhauser 1996). Annual plants are located in eastern Maine.

What are the Functions of Eelgrass?

Eelgrass stabilize and bind substrates and absorb nutrients from sediments. They reduce water currents by frictional forces, dampen wave energy and slow erosional processes. They are primary producers removing inorganic nutrients from the sediments and the water column and through photosynthesis convert them into organic matter. The blades are food for grazing invertebrates, fish, American brant, Canada geese, black ducks and other waterfowl. The remaining dead plant matter adds substantial amounts of organic biomass to nearshore deposits of detritus and benthic habitats. The detritus fuels the microbial food web which, in turn, provides food for invertebrates, fish, and birds. Eelgrass beds add structural complexity and surface area to intertidal and subtidal environments. Blades become covered in an organic felt composed of microscopic plants (benthic diatoms), bacteria and grazers. They provide shelter from predation and wave action; nursery grounds for clams, fish, blue mussels, sand shrimp, lobsters, crabs, and other aquatic organisms; attachment sites for epiphytes, snails and larvae; and shading from solar radiation. Shorebirds and commercially important fish species prey on worms and invertebrates living in and feeding on eelgrass. Species abundance and diversity is high compared to unvegetated sites (McRoy and Helfferich 1977; Short et al. 1993; Wippelhauser 1996)

What are the Economic Values of Eelgrass?

Eelgrass supports several commercial fisheries by providing structure, shelter, and foraging habitat in mud flats, mixed sediment or sand flat environments. American lobsters, blue mussels, soft-shell clams, razor clams, blood worms, sand worms, rock crabs, sand shrimp, periwinkles, and winter flounder all benefit from eelgrass beds. Eelgrass contributed to seafood landings in 1997 valued at over $153 million (NOAA 1997).

How Sensitive is Eelgrass to Disturbance and Development?

Eelgrass is a multi-functional productive habitat that has been classified by DEP as having a high sensitivity to disturbance and development (see Habitat Ranking).

What are the Threats to Eelgrass Communities?

- Shading from physical structures: Shading blocks light and reduces growth. Even temporary floats can smother and kill eelgrass beds.
- Removal and/ or disturbance of habitat: Dredging, filling, impoundment of water, sediment loading, and boating activity shades, smothers or removes eelgrass and its habitat.
- Resuspension of sediments: Resuspension of sediments from dredging, filling, boating and fishing activity shades and smothers eelgrass.
- Pollution: Run-off of sediments and pollutants from upland construction sites, freshwater discharges, nutrient rich groundwater, industrial discharges, chlorinated effluent, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and others all damage eelgrass. Eutrophication from upland point and non-point source pollution stimulates phytoplankton and algal growth (epiphytes) reducing light levels reaching eelgrass beds.

How Should Eelgrass be Managed?

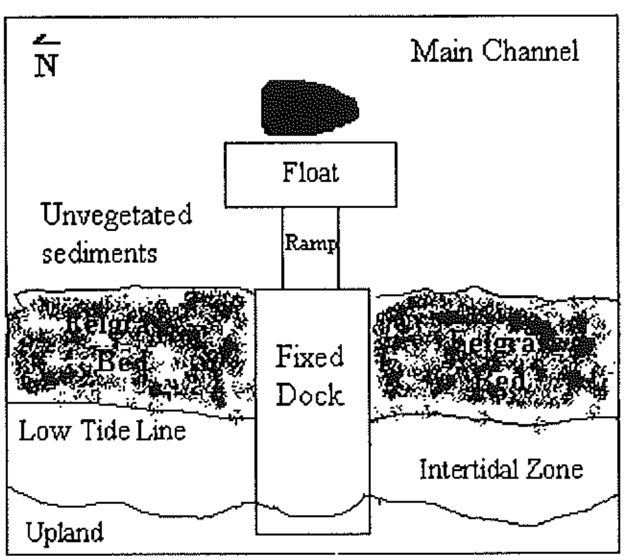
- Avoid permitting activities that remove, shade or smother eelgrass.
- Avoid sediment disposal on or around eelgrass.
- Minimize activity around eelgrass beds.
- Water dependent structures: structures should be place in areas that will not shade eelgrass in the winter or the summer. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see guidelines below). Avoid permitting activities where boat traffic can shade or scour beds. Discourage the use of temporary or permanent floats. Encourage the use of

temporary pile driven piers with removable decking. Encourage the joint use of a public pier instead of the creation of a new structure.

- If applicable, determine if current velocity, tidal flows, shoreline contour, water clarity or wave energy will be altered due to the proposed activity. If so, design project to minimize physical changes. Compensate for the loss of eelgrass beds within the proposed site as well as impacted adjacent eelgrass habitats.
- Discharges of freshwater or pollutants should be minimized around eelgrass.
- New developments in the upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.
- Transplanting eelgrass beds should be part of the mitigation plan when there are direct permanent losses of eelgrass habitats (see Fonseca et al. 1982; Short et al. 1999). Compensation for eelgrass losses is often required by the Environmental Protection Agency (EPA) in the ratio of 3:1 (replacement:loss). Mitigation must be completed and proven successful before development is permitted (Wippelhauser 1996).

Guidelines for Pier Design in or around Eelgrass Beds

To reduce impacts from shading, design plans should consider the height, the width, length, and orientation of the structure. The height of the dock and the orientation are the most important factors to reduce shading. Docks and piers should be at least 9 feet above the marine bottom. The best orientation to reduce shading is to place the structure within 10° of a north-south orientation. The narrower the structure the better. The piers should be less than 6.5 feet wide. Height needs to be added to the structure if it is oriented beyond 10° of N-S (0.7 feet should be added to the height requirement for every 10° increment). If a dock is wider than 6.5 ft, 1.3 feet needs to be added to the height (in addition to the 10 foot base), for every 3.3 feet of width. Docks should be long enough to extend to deep navigable waters unvegetated by eelgrass to prevent direct damage by boats. Larger boats should be moored off the dock and accessed by dingy. Temporary floats cause severe damage and should be avoided (see Burdick and Short 1999 and the Dock Design with the Environment in Mind CD Rom by Burdick and Short 1998 for additional guidelines).



Summary of the Functions and Values of Eelgrass (adapted from Short, F.T. et al. 1999).

Functions	**Values**
1. Three dimensional canopy structure	Complex habitat Refuge from predation, wave action, solar radiation Nursery area for invertebrates and fish Attachment site for larvae and eggs Supports commercial fisheries
2. Primary production and seed production	Food for invertebrates, fish, and waterfowl Supports commercial fisheries and wildlife
3. Increases secondary production	Support of the food web Supports commercial fisheries Supports shorebirds
4. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
5. Sediment sink and trap	Improves water quality Increases area of benthic habitat Reduces coastal erosion Supports commercial fisheries
6. Dampens current and wave energy	Prevents erosion and resuspension of sediments Increases sedimentation
7. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
8. Structure for the attachment of algae, diatoms and animals	Food resources for consumers Increases primary production Supports commercial fisheries
9. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries Slows shoreline erosion
10. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
11. Self-sustaining ecosystem	Encourages recreational and educational activities Landscape level biodiversity

Functions and Values of Kelp:

What is Kelp?

Kelps are brown algae that have one of the highest rates of primary productivity in the world (Lee 1992). The family of kelps in Maine include *Laminaria* spp., *Alaria* spp., *Agarum* spp., *Chorda* spp., and *Saccorhiza* spp. They differ from eelgrass because they lack true roots, stems and leaves. They absorb nutrients through the blades. Nutrients are transported to the stalk and holdfast. Kelps are intolerant of desiccation and restricted to low intertidal and subtidal environments (Wippelhauser 1996). The coastal kelps of Maine are cold water species. *Laminaria* spp. cannot survive in water temperatures above 55°F (Lee 1992). Vegetative growth is greatest when concentrations of nutrients are optimal and light is available. Depending on the chemical and physical characteristics of a region, maximum growth occurs between late winter and summer. Ice scour limits growth in the winter months. The life span of some subtidal *Laminaria* is approximately three years whereas intertidal species are annuals (Wippelhauser 1996).

Where is Kelp Located in Maine?

Kelps live in low intertidal and shallow subtidal moderate to high wave energy environments. They attach to ledge, boulder, and mixed coarse environments on the mainland and off-shore islands of Maine. Depending on the species, water clarity, and predation pressure, some kelps can live at depths of 130 feet (Vadas and Steneck 1988). Unlike rockweed, kelp beds are not as common in Maine. Predation by sea urchin and other marine organisms periodically reduces kelp biomass. In addition, suitable wave and tidal energy, water clarity and subtidal geological features limit their distribution and growth.

What are the Functions of Kelp?

Kelp are primary producers converting inorganic nutrients into organic matter for secondary consumers. They play an essential role in removing inorganic nutrients (e.g.

phosphate and nitrate) and converting them into usable products for commercial and ecological use. Like eelgrass, portions of the algae break apart and are transported by tides and currents to the nearshore forming large deposits of organic detritus. This detritus forms a base of estuarine and marine food webs. The kelp beds add structural complexity and surface area to an otherwise barren environment. They provide shelter from predation and wave action, attachment sites for epiphytes and larvae, food resources, and nursery grounds for fish, shellfish and lobsters, and protection from ultra violet radiation. The holdfasts offer unique microhabitats for brittle stars, scaleworms and other invertebrates. Species abundance and diversity is high in kelp beds compared to unvegetated sites. They are the main food resource for snails, amphipods, chitons, limpets, and urchins. The detritus formed from the dead algal matter is consumed by bacteria, small invertebrates and worms which, in turn, feed birds, fish and mammals. Large kelp beds reduce water currents by frictional forces and increase sedimentation (Wippelhauser 1996). Their presence reduces shoreline erosion.

What are the Economic Values of Kelp?

Adult kelps are harvested, processed and sold as health food, nutritional supplements and thickening and stabilizing agents in common household foods. Approximately 150,000 pounds of kelp are harvested annually by just two companies in eastern Maine. Much more is harvested in Maine but not reported to regulatory agencies. Blades are also collected for food for sea urchin aquaculture and packaging material for lobsters.

Kelps are consumed by commercial species and create habitat used by commercially valuable fish and invertebrates. Kelps are the most important food for green sea urchins. In 1997, sea urchin landings in Maine were valued at over $20 million. In addition to direct use, Atlantic cod and American lobsters forage and seek shelter in kelp beds and Atlantic herring deposit eggs on kelp fronds. Kelps were key supporters of seafood landed and valued at $150 million in 1997 (NOAA 1997).

How Sensitive are Kelps to Disturbance and Development?

Kelps are classified by DEP as a high sensitivity habitat (see Habitat Rankings). They are ecologically and commercially valuable, sensitive to disturbance and a limited resource in Maine.

What are the Threats to Kelp Communities?

- Shading from physical structures: Shading blocks light and reduces growth potential.
- Removal and/ or disturbance of habitat: Dredging, blasting of ledges, removal of boulders, impoundment of water, scouring by boat traffic, removal or dragging by fishers, and sediment loading smothers or removes kelp and its habitat.
- Pollution: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, chlorinated effluent, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and other activites all damage kelp. In addition, phytoplankton blooms, caused by nutrient loading from pollution, cause reductions in light levels harming kelp beds.
- Resuspension of sediments: Resuspension of sediments from dredging, filling, boating and fishing activity smother kelp. Resuspension of sediments may resuspend

larvae and small invertebrates changing the community structure of the habitat and endangering kelp beds.

- Over-harvesting

How Should Kelp be Managed?

- Avoid permitting any activities in kelp beds.
- Avoid permitting any activities that remove kelp and kelp habitat.
- Water dependent structures should be placed in areas that will not shade kelp or indirectly impact kelp beds. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade or scour beds.
- Survey areas for lobsters. Lobsters may concentrate in large kelp beds or use smaller patches for shelter.
- Avoid sediment disposal on or around kelp beds. Avoid activities that will resuspend sediments around kelp beds.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around kelp beds.
- New developments in the upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Kelp Beds.

Functions	Values
1. Primary production	Food for invertebrates and fish Support commercial fisheries and wildlife Commercial harvested for food and nutrients
2. Three dimensional canopy structure	Create habitat in barren environments Refuge from predation, wave action, solar radiation Nursery grounds for cod, shellfish and lobsters Attachment site for larvae and herring eggs Microhabitats of animals in holdfasts Supports commercial fisheries
3. Increases secondary production	Supports the food web Supports commercial fisheries
4. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
5. Dampens current and wave energy	Reduces shoreline erosion Increases sedimentation
6. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
7. Structure for the attachment of algae, diatoms and animals	Food resources for consumers Increases primary production Supports commercial fisheries
8. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
9. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
10. Self-sustaining ecosystem	Increases biodiversity

DEP Habitat Ranking

Objective:

The habitat ranking was developed to rank marine habitats with justification from high to low sensitivity to disturbance and development activity. These rankings should be used to discourage activity in habitats with a higher ranking and alternatively, redirect activity to habitats with a lower ranking. Activities taking place in habitats with a high and moderate ranking should receive a greater level of scrutiny in the permitting process. It may also be used to justify compensation for the loss of functions and values from permitted activity.

Background:

The following table ranks marine habitats according to ecological and commercial functions and values as well as the habitat's sensitivity to perturbations. The rankings were determined by marine biologists in the Division of Environmental Assessment. The ranking are based on scientific research and our knowledge of intertidal and shallow subtidal marine environments.

Habitats are ranked as having a low, moderate or high ranking based on the number of important ecological attributes (see listing below). In general, the more attributes or functions maintained by the habitat the greater the ranking. Moderate and high ranking habitats are habitats that we consider ecologically and economically valuable regions that are more likely to be negatively impacted by development than other resilient marine habitats. Some attributes, like nutrient recycling, could be applied to all habitats in some degree. However, only habitats that have a significant role in nutrient recycling are listed. In addition, these rankings are based on the general understanding of functions and values of marine habitats. Upon field examination of specific sites, researchers may find that some habitats have fewer or greater number of attributes.

Some habitats have different rankings based on their exposure to air, freshwater and wave energy. As a general rule, low intertidal zones, regions that receive less tidal exposure, have a greater number of attributes and, therefore, are more sensitive to disturbance. Dry high intertidal areas are inhospitable regions that are exposed to temperature fluctuations, desiccation, solar radiation, weathering and freshwater. Therefore, they support species that are widely distributed, adaptive to environmental changes, and less sensitive to disturbance.

DEP habitat rankings are based on habitats with one or more of the following attributes:

A. Nursery ground for commercial species
B. Primary production / oxygen production
C. High diversity
D. High primary and secondary production
E. Shelter
F. Structure for attachment of settling larvae
G. Food resources for one or more functional groups
H. Variety of functional groups represented
I. Sediment and nutrient sink and/or source
J. Nutrient recycling
K. Production and export of detritus
L. Habitat dependent species
M. Rare or endangered animals
N. Rare or endangered plants
O. Foraging areas for shorebirds and/or wading birds
P. Shorebird roosting and/or staging areas
Q. Supports terrestrial birds
R. Supports terrestrial mammals
S. Reduces coastal erosion
T. Supports commercial fisheries
U. Supports lobster fishery
V. Supports tourism industry
W. Geographically isolated and rare populations of species
X. Haul out and pupping sites for gray and harbor seals
Y. Foraging areas for waterfowl and/or seabirds
Z. Nesting habitat for endangered birds (e.g. piping plover, least tern)
AA. Supports anadromous fish

HABITAT	LOCATION	DEP HABITAT RANKING	JUSTIFICATION
Artificial Substrates:			
Artificial or engineered structures	High to Low intertidal	Low	f, g variable depending on structure/materials
Artificial man-made sediments (e.g. woodchips)	High to Low intertidal	Low	Low quality habitat Variable
Degraded areas / previously impacted	High to Low intertidal	Low	Variable
Boulder Beaches:			
Boulder beaches with algae	Low intertidal	High	a,b,c,d,e,f,g,h,j,k,l,o,s,t,u,y
Boulder beaches with algae	Mid intertidal	Moderate	b,e,f,g,h,j,k,s,y
Boulder beaches (no algae)	High intertidal	Low	g
Ledge:			
Ledge with attached algae (or potential for algae - i.e. site has been grazed bare by urchins)	Low intertidal	High	a,b,c,d,e,f,g,h,j,k,l,o,s,t,x,y
Ledge (with algae)	Mid intertidal	Moderate	b,c,d,e,f,g,h,k,o,s,v,x,y
Ledge (no brown or red algae)	Mid - High intertidal	Low	f,g,n,o,p,q,v,x
Mixed Coarse and Fines:			
Mixed coarse and fines with algae	Low intertidal	High to Moderate	a,b,d,e,f,g,h,i,j,k,o,s,t,u
Mixed coarse and fines (no brown or red algae)	Mid and High intertidal	Low	g,p,f
Cobble beaches (no brown or red algae)	High to Low intertidal	Low	g,p
Gravel beaches (no brown or red algae)	High to Low intertidal	Low	g,p
Mud Flats:			
Mud flats	High to Low intertidal	High	a,b,c,d,e,f,g,h,i,j,l,o,p,t,w
Organic Habitats:			
American oyster bars	All	High	c,d,e,f,g,h,t,w
Mussel bars	Low intertidal	Moderate	a,d,e,f,g,s,t
Salt Marshes:			
Salt marshes	All	High	a,b,c,d,e,f,g,h,i,j,k,l,m,n,p,q,r,s,t,v,y,z,aa
Sand Beaches:			
Sand beaches	Low intertidal	High	d,g,i,l,m,o,t,v,y
Sand beaches	Mid and High	High to Moderate	g,i,j,l,m,n,o,p,q,v z(above high tide line)
Sand Flats:			
Sand flats	High to Low intertidal	High	a,b,c,d,e,f,g,h,i,j,l,o,p,t,w

Subtidal Habitats			
Ledge with attached algae (or potential for algae - i.e. site has been grazed bare by urchins)	Subtidal	High	a,b,c,d,e,f,g,h,j,k,l,s,t,u,y,aa
Mixed coarse	Subtidal	High	a,b,c,d,e,f,g,h,j,k,l,t,u,y,aa
Sublittoral zone	Shallow subtidal	High	a,b,c,d,e,f,g,h,i,j,l,r,t,u,w,y,aa
Unconsolidated sediments	Subtidal	High	a,b,c,d,e,f,g,h,i,j,l,r,t,u,y,aa
Vegetated Habitats:			
Eelgrass beds	All	High	a,b,c,d,e,f,g,h,i,j,k,l,o,s,t,w,y
Irish moss (Chrondrus sp)	All	High	a,b,c,d,e,f,g,h,j,k,l,o,s,t,u,y
Kelp beds	All	High	a,b,c,d,e,f,g,h,j,k,l,s,t,u,y,aa
Rockweed - on all habitats	Mid-low intertidal	Moderate	a,b,d,e,f,g,h,i,j,k,o,s,t

ANNUAL AND SEASONAL VARIABILITY

August 1999

March 1999

Photo #1. These two photos were taken at the same coastal location in the summer and the winter. The photo on the left shows a close up of the tall grasses of the fringing salt marsh in August. The photo on the right shows the fringing salt marsh after it has died back and been scoured by rafting ice. A majority of the functions and values of salt marsh are not apparent in the wintertime.

The marine environment, like terrestrial habitats, fluctuates annually and seasonally. Intertidal and shallow subtidal habitats are influenced by the atmosphere and the oceans. Variations in the physical properties of marine waters drive changes in the plant and animal community. For example, temperature and rainfall greatly influence interannual and seasonal variability. Warmer summer temperatures in the oceans favor species, like the green crab, that can tolerate warm temperatures, reproduce successfully and flourish. Conversely, warm temperatures kill boreal cold water species or cause them to move offshore seeking cooler waters in the summer. Heavy rainfall or flooding events can also destroy many intertidal invertebrates while favoring the growth of some forms of macroalgae and phytoplankton.

In the winter, freezing temperatures, lack of light, ice scour, lack of food and other physical and biological factors affect the intertidal environment. These factors cause a die off of plants and animals, a migration by mobile species to sheltered sites or other biological interactions. In low energy environments, ice buildup in the winter scours plants and removes epifauna and infauna on tidal flats (Whitlatch 1982). Depending on the severity of the winter, shallow surface sediments can freeze 5 cm to 10 cm below the surface (Whitlach 1982). The freezing of sediments can kill benthic species or force them to burrow below surface layers. Frozen sediments reduce access and foraging by birds (Whitlach 1982). Dense algal mats on tidal flats can form in the winter due to the reduced grazing pressures from herbivores (Whitlatch 1982). Many species, like the mudsnails, *Nassarius obsoletus*, over-winter subtidally to avoid low temperatures on intertidal flats (Whitlatch 1982). Adult lobsters also move offshore in the winter (Diane Cowan, personal communication). Some fish swim south to warmer waters. Abundance and diversity of marine life in the subtidal may be greater in the winter than the summer due to offshore migrations of intertidal species and southward migrations of northern species seeking warmer waters off the coast of Maine (Les Watling, personal communication).

As the days lengthen and the temperatures warm in the spring and summer, species return to the intertidal environment to develop, breed and forage. Planktonic larvae, like barnacles, crabs and snails, settle out of the water column and colonize intertidal habitats between April and July. Mudsnails and other marine invertebrates that survived the winter return to the flats in the spring, feed and reproduce in the summer releasing their young into the height of the plankton bloom (Whitlatch 1982). Sand worms burrow out of the mud and spawn between March and June (Whitlatch 1982). Adult and larval fish are seasonal intertidal visitors, foraging during summer months on organisms living in intertidal flats and salt marsh (Whitlatch 1982). Adult lobsters return to low intertidal habitats in late spring and summer. The highest population density of juvenile and adult lobsters in low intertidal mixed coarse habitats is between May and November (Diane Cowan, personal communication).

Birds also have seasonal migrations and foraging and breeding behaviors. Shorebirds have a spring migration to the Canadian arctic breeding grounds and a fall migration to South American wintering grounds (MIF&W 1994). The fall migration is between July and November and the spring migration is between mid-April and early June (USF&W 1980). As many as 150,000 shorebirds, passing through Cobscook Bay in Downeast Maine, forage and roost on intertidal flats during the fall migration (MIF&W 1994). The spring shorebird migration brings fewer numbers of birds to Maine (MIF&W 1994). In Casco Bay and other places in Maine, large numbers of waterfowl such as eiders, old squaws and gulls, over-winter and feed on offshore islands in the winter. In the summer great black-backed gulls, terns, double-crested cormorants, herring gulls, and eiders nest and raise chicks on offshore islands and exposed ledges of Maine (USF&W 1980).

Management Considerations

Seasonal and interannual variability need to be considered while reviewing marine wetland assessments. Winter sampling will miss many species that live and breed on intertidal habitats in the summer thus underestimating the use of the habitat by flora and fauna. If ice scour doesn't affect the habitat, rockweed and other macroalgae may survive throughout the winter months but the fauna associated with the macroalgae will be minimal. Only species tolerant of freezing temperatures will be present in the intertidal in the wintertime.

- Field studies should be conducted between April and November before cool temperatures limit the availability of species.

GLOSSARY

Amphipods: small shrimp-like crustaceans that live within the wrack, algae and on the sediments in all intertidal zones. Amphipods feed on detritus and algae.

Beach hoppers: small amphipods that live in high intertidal wrack.

Benthic species: animals or plants that live on or in the bottom sediments.

Biogeography: the science concerned with the geographical distribution of animal and plant life.

Boulders: stable rocks greater than 256 mm (10 ") but less than 3 m (~10 ft) in diameter that cannot be rolled by wave action.

Bryozoans: sessile, colonial animals that form stalks or encrustations over rocks. They feed by capturing tiny particles of plankton or detritus from the water column.

Chiton: a single shelled mollusk in the Class Polyplacophora that attaches to hard substrates with a muscular foot. Chitons are grazers consuming algae and diatom films.

Cobble: unstable rocks less than 256 mm (10 ") but greater than 64 mm (2.5") that can be over turned by wave action.

Deposit feeders: animals that feed on the detritus that collects on the substrate at the bottom of the water column (e.g. bloodworms, sea cucumbers).

Desiccation: the drying out of intertidal plants and animals exposed to air, wind, and sun.

Detritus: dead organic plant, algae and animal matter mixed with live bacteria.

Diatoms: microscopic benthic or pelagic single celled algae from the class Bacillariophyceae.

Direct disturbance: the area of habitat that is directly impacted by development (e.g the footprint of the activity, area filled or dredge, area under pier).

Echinoderm: marine spiny-skinned invertebrates in the Phylum Echinodermata that include sea urchins, sea cucumbers, sea stars, sand dollars and brittle stars.

Epibenthic species: animals or plants that live on the bottom.

Epiphyte: plant or algae living on another plant, algae, animal or substrate.

Epifauna: animal living on a plant, algae, animal or substrate.

Epiflora: plants or algae living on a plant, algae, animal or substrate.

Eutrophication: the process of becoming better nourished either naturally by processes of maturation or artificially by fertilization. Eutrophication often leads to algal blooms and/or alterations of natural marine communities.

Forage fish: small fish that are prey for fish, birds, and mammals (e.g. sand lance).

Fringing salt marsh: a narrow band or patch of salt marsh in the high intertidal.

Functions: biological, chemical, geological, or chemical properties within a self-sustaining marine environment (e.g. fish and wildlife habitat, sediment trap).

Gravel: small pebbles between 2 mm (.04") and 64 mm (2.5") in diameter.

Habitat: a place where plants and animals live, breed, take shelter, and forage.

Habitat dependent species: species that are dependent on only one or a few types of habitats for reproductive success. They can not adapt to all habitat types. For example, some small crustaceans can only live in the low intertidal zone on high energy sand beaches.

Haul out: resting sites and pupping sites for marine mammals. Haulouts in Maine are typically ledge habitats on isolated portions of the mainland and offshore islands.

Holdfast: the "roots" of algae used to attach to hard substrates.

Indirect disturbance area: area of habitat that may be indirectly impacted by the proposed activity (e.g. area of potential impacts from docking and departing, shaded habitats, regions impacted by changes in sediment flow or currents).

Infauna: animals that live in the sediments (e.g. clams, worms).

Inflora: algae that live in the sediments (e.g. diatoms).

Intertidal zone: the part of the littoral zone above low-tide mark that displays a gradient of biological communities from low to high water.

Inorganic nutrients: dissolved nutrients that do not contain carbon as a principle element (e.g. nitrate and phosphate) that are absorbed by algae and required for primary production.

Ledge: stable bedrock > 3 m (~10 ft) in diameter.

Mean low water line: the mean of the low water heights observed over a specific 19 year cycle (National Tidal Datum Epoch) as defined by NOAA.

Metamorphic rock: rock composed of altered layers of sand and mud.

Mixed coarse and fines: flats consisting of a mixture of rocks, boulders, gravel, sand, cobbles, and mud.

Mud: very fine particles of silt and clay less than .06 mm in diameter that are usually mixed with organic matter.

Non-point source pollution: pollution originating and discharging into the ocean from an indirect source such as stormwater run-off from parking lots.

Nudibranchs: mobile shell-less gastropods also known as sea slugs. Nudibranchs are predatory animals consuming sponges, tunicates, bryozoans or other small invertebrates.

Nursery ground: a region where larvae or juveniles settle, seek shelter, feed and mature.

Nutrient recycling: the bacterial driven conversion of detritus back into inorganic nutrients.

Organic sediments: intertidal or subtidal sediments containing large percentages of peat, sawdust, wood chips, leaf litter or other organic matter.

Opportunistic species: animals that can adapt to environmental changes and stresses and flourish.

Point source pollution: pollution discharging from a known source such as a pipe.

Plankton: microscopic algae, eggs, larvae, small fish and invertebrates that are free-floating and a drift in the water column.

Primary production: the production of plant or algal matter by means of photosynthesis.

Roosting area: an area where shorebirds sleep and preen during high tide. These protected sites are critical for shorebirds to maintain fat reserves, lower stress and reduce predation.

Sand: small sediment granules between .06 mm and 2 mm in diameter.

Sand fleas: small amphipods that live in high intertidal wrack on sand beaches and flats.

Seabirds: birds that spend a majority of their lives living and feeding at sea or along the sea coast. Seabirds include cormorants, gulls, terns, fulmars, puffins, shearwaters, storm petrels, murres, and albatross.

Secondary production: the production of animals that graze on plants or algae (e.g. clams, mussels, shrimp, periwinkles, sea urchins).

Sediment sink: a region that stores sediments.

Sensitivity: animal and plant communities that are susceptible to small changes within their environments.

Settlement: the act of settling on the benthos or other habitats by early developmental stages of animals. Many marine organisms live and drift in the plankton as larve and settle out to complete their life cycle.

Shelter: refuge for animals from predation, desiccation, wave and current action, sun light and other environmental stresses.

Shorebird: any sandpiper, plover, turnstone, godwit, curlew, dowitcher, and phalarope in the Order Charadriiformes.

Staging area: an area where migrating shorebirds forage, increase weight, and rest for up to two to three weeks before embarking on their transatlantic migration.

Storm surge: the rise of salt water onshore above the normal water level on the open coast due only to the action of wind stress on the water surface.

Stormwater runoff: runoff from land caused by rain or melting snow.

Subtidal: area seaward of the lowest extent of the intertidal zone.

Top consumers: animals like large fish, birds and mammals that are at or near the top of the food chain.

Tunicates: marine and estuarine invertebrates also known as sea squirts. They are colonial or solitary animals that filter feed on plankton, detritus, and microscopic algae.

Value: a benefit or result of one or more biological, physical, chemical and/or geological functions that are of high importance to society (e.g. commercial fisheries, water quality) and/or are essential for maintenance of the ecological health of an environment (e.g. recycling of nutrients by bacteria results in the release of new sources of nutrients for plant growth).

Wading birds: Long legged birds that feed by wading and catching their prey in shallow water. Wading birds include herons, egrets, bitterns and ibises.

Waterfowl: birds that breed in fresh water, winter along the coast and forage by diving or dabbling in fresh, estuarine and marine waters. Waterfowl include geese, loons, grebes, bufflehead, goldeneyes and eider ducks.

Wintering habitat: resting, foraging, and roosting areas for birds in the wintertime.

Wrack: dead decaying plant, algal and animal matter deposited on high intertidal portions of the beach by wave and tidal action. Wrack deposits contain live populations of sand fleas and bacteria.

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APPENDICES

Appendix A

Maine Dept. of Environmental Protection
Permit-by-Rule Standards
June 1996

Activity	Planning the Project to Comply with the DEP's Permit-by-Rule Standards
1. soil disturbance	Regulated only if the possibility exists that soil or fill materials may wash into a regulated water body (i.e., not regulated if existing barriers such as ice berms and retaining wall or a negative slope will prevent runoff): permit-by-rule applicable only if the work involves soil disturbance and/or fill placement ***adjacent to (i.e., within 100 feet, measured horizontally, from the normal high water line) but not in*** a coastal wetland, freshwater wetland, great pond, river stream or brook; [**Note**: soil disturbance in areas adjacent to freshwater wetlands is exempt from this standard except for those wetlands listed under 480-C.1.B.]
2. water intake and monitoring devices	Pipes must not significantly affect water levels or flows in the water body: applies also to drilled wells in or adjacent to freshwater wetlands or adjacent to coastal wetlands, great ponds, rivers, streams or brooks [**Note**: Water line placement to a single family house adjacent to a great pond is exempt from NRPA regulation provided excavated trenches are backfilled, riprapped and seeded to prevent erosion.]
3. replacement of structures	A replaced structure may not exceed the dimensions of the previously existing structure, nor may it extend any further into the water body or wetland, except applicants may replace retaining walls with properly installed riprap (see riprap installation, below)
4. movement of rocks or vegetation	The standards allow for only minimal movement (no more than ten feet) of rocks or removal of vegetation from below the normal high water line of a great pond, river, stream or brook to provide access for swimming or navigation
6. outfall pipes (including ditches and drain tiles)	PBR applies to the installation and maintenance of permanent outfall pipes, ditch outlets and drain tiles for discharges of storm water, ground water and other discharges approved by the DEP (**Note:** Except for uncontaminated groundwater and storm water from residential and small commercial/industrial facilities, applicants must receive a wastewater discharge license from the DEP)
7. riprap	PBR applies to the placement of riprap along the shoreline of coastal wetlands (only to protect a structure within 100 feet of the eroding bank and never in any portion of a coastal sand dune system or in areas containing soft-bottom/mudflat sediments or salt marsh vegetation), great ponds, rivers, streams and brooks ***only where erosion already***

	exists and cannot be controlled by planting vegetation. Riprap must not extend higher on the bank than the level at which vegetation can be established to control erosion (1-3 feet above normal high water). Applicants must plant trees and shrubs above the riprap to replace any material removed. Vegetation planted must be similar in type and placement to that removed. Riprap slope must not exceed one horizontal to one vertical, nor be shallower than three horizontal to one vertical. Applicants must:
	• anchor riprap at the base of the existing bank by placing the bottom row of rock in a trench excavated at least to a depth equal to the height of the largest rock; • place a layer of filter fabric or crushed rock or washed gravel under the riprap to prevent the washing of soil particles into the water; • not install any fill material below the normal high water line and must cutback eroding banks to required slopes to allow for riprap installation; • not put riprap in front of a retaining wall in a manner that it extends further into the water; and • combine riprap with tree and shrub planting to provide bank stabilization, shading of the water and cover for wildlife along any river, stream or brook.
8. utility line crossings	PBR applies to the installation, maintenance and replacement of utility lines over, submerged under or adjacent to: coastal wetlands, freshwater wetlands, great ponds, rivers, streams or brooks, excluding "outstanding river segments" identified in Title 38, Section 480-P. (**Note**: The installation of utility cables to a single family house adjacent to a great pond are exempt from NRPA regulation provided excavated trenches are backfilled, riprapped and seeded to prevent erosion. Overhead service drops less than 1,000 feet long for telephone or electrical service in freshwater wetlands.)
9. bridges, culverts and fords	PBR applies to the construction of a permanent road crossing of a river, stream or brook using either a bridge or culvert ***except for***: • "outstanding river segments" identified in Title 38, Section 480-P; • any river subject to state mandated Shoreland Zoning; and • coastal wetlands, freshwater wetlands, floodplain wetlands greater than 10 acres and great ponds. (**Note**: maintenance and repair of public and private crossings are exempt from the NRPA provided that erosion control measures prevent sedimentation, the activity does not block fish passage; and there is no additional intrusion into the river, stream or brook)
10. State transportation facilities	PBR is applicable only to projects conducted by the Maine Department of Transportation or the Maine Turnpike Authority
11. restoration of natural areas	PBR applies to the restoration of altered portions of coastal wetlands, freshwater wetlands, great ponds, rivers, streams, brooks (or areas adjacent to these protected natural resources) to their natural conditions through the removal of fill, structures or deposited debris. PBR also

	applies to the restoration of adjacent areas through recontouring or grading to pre-existing elevations, replanting to pre-existing or similar vegetation and correcting for inundation from previous flooding. Does ***not*** apply to: • restoration or replacement of structures or to draining of freshwater wetlands to convert an area to upland; • conversions of existing natural wetlands to a different type of wetland through flooding, inundation or other means; • dredging silt, sand or soil materials naturally deposited into a coastal wetland, freshwater wetland, great pond, river, stream or brook; • mining of gravel or other minerals from rivers, streams or brooks; • replacement of eroded soil material in areas above, below and adjacent to the normal high water mark of coastal wetlands, freshwater wetlands, great ponds, rivers, streams or brooks; and • removal of dam structures.
12. fisheries and wildlife habitat creation and water quality improvement projects	PBR applies to alterations in and adjacent to coastal wetlands, freshwater wetlands, great ponds, rivers, streams and brooks, provided the alterations are exclusively to create or enhance habitat for fisheries or wildlife or projects to improve water quality. Activities must be conducted by public utilities and municipalities under the supervision of public natural resource agencies. Activities allowed include, but are not limited to: • fishway installation; • the construction of artificial reefs, nesting platforms and boxes; • maintenance, installation or modification of dam structures; and • the construction and maintenance of nutrient retention structures
13. piers, wharves and pilings	PBR applies to the construction or expansion of pile-supported piers and wharves and the installation of pilings in coastal wetlands. PBR also applies to the construction of structures for water dependent uses (e.g., bait sheds) on pile-supported piers and wharves.
14. public boat ramps	PBR applies to the construction of new or the replacement of existing public boat ramps (no more than two new lanes or a total of two upon completion) and carry-in launch areas, including associated parking and accessways (walk-ways or stairs, portage trails, etc.) in or adjacent to a protected natural area. Such activities include projects by public natural resource agencies, municipalities and owners of federally-licensed hydropower projects. Larger projects or projects where any portion of the ramp or related facilities is located in, on or over emergent marsh vegetation or intertidal mudflat are not eligible for permit-by-rule.
15. general permit for selected activities in coastal sand dune systems	PBR applies to the following specific activities, provided the activity is undertaken in conformance with the DEP's Coastal Sand Dune Rules (Chapter 355): • replacement of existing seawalls; • dune restoration or construction; • beach nourishment;

	• walkways and driveways, open fences and decks in back dune areas classified as "A," "B" or "C" flood hazard areas; • movement of sand and cobble from the front of buried seawalls using machinery; and • new development or additions to existing development in back dune, non-flood ("C" zone) areas of coastal sand dune systems ***that are not expected to be damaged due to shoreline change within the next 100 years based on historic and projected trends***. [**Note**: The DEP will review such permit-by-rule applications on a case-by-case basis. If the DEP determines that the potential exists for damage from shoreline change, the DEP will require a complete NRPA permit application. This PBR section ***does not apply*** to the construction of or additions to existing single family dwellings in "A" or "B" flood hazard zones or to any structures in "V" hazard zones.]
16. transfers and permit extensions	To transfer an NRPA permit from the original permit holder to a new owner, an applicant must submit: • an affidavit attesting to the fact that the new owner has received, read, understands the terms and conditions and will fully comply with the original terms and conditions of the permit; and • copies of the permit to be transferred along with documents establishing proof of ownership of the property on which the project is located or sufficient title, right or interest to complete the project in accordance with the requirements of the permit and the NRPA. To extend a permit, an applicant must submit a copy of the permit along with a written reason/explanation for the extension request.
17. general permit for maintenance dredging previously approved by DEP	PBR applies to the renewal of DEP permits for dredging in coastal wetlands, freshwater wetlands, great ponds, rivers, streams and brooks provided that the dredged material: • will be disposed of in conformance with Maine Solid Waste Law on land and not in any protected resource area; • is located in an area that was dredged within the last 10 years; and • is not located within 250 feet of an area identified as significant wildlife habitat by the Maine Department of Inland Fisheries and Wildlife (DIF&W). [Note: Applicants can determine whether or not the project is located in or near a significant wildlife habitat area by contacting the local regional DIF&W office]

Appendix B

Analysis of Intertidal Habitat Distribution and Abundance Data

The data on the distribution and abundance of seven intertidal environments in Maine were created from the Coastal Marine Geological Environments (CMGES) on GIS at DEP. The CMGES were created by digitizing and enlarging the original Coastal Marine Geologic Maps (1:40,000) created by Barry Timson in 1976. The digitized maps (7.5 minute quadrangles) for GIS were enlarged to 1:24,000. The Timson maps, delineating 50 different coastal environments greater than 150 m^2 in the supratidal, intertidal and subtidal, were drawn from aerial photographs taken during low tide in 1960 for the entire Maine coast.

For the purposes of this study only information on the intertidal environments was selected, sorted and combined from 102 quadrangles.

Intertidal environments were combined into seven habitats (Appendix B Table 1). The seven intertidal habitats are salt marsh, sand beach, rock, boulder, mixed coarse and fines, sand flat, and mud flat. All habitat types for this study were based on the Brown (1993) and Cowardin et al. (1979) classification of marine environments (Appendix B Table 2). The reductions were based first on the geology of an environment and secondarily on the biological characteristics of the environments. Washover fans (Bw) and vegetated point of lateral bars (Mp), two habitats not characteristic of intertidal environments were excluded from the analysis.

Data tables of the area (m^2) of environments from 102 CMGES quadrangles were download, sorted and reduced into habitat coverage. Quads were divided into island and mainland coverage. Data for each intertidal habitat were summed and converted into acreage for each quad.

For the purposes of comparison, data from the entire coast of Maine was consolidated into four regions. These regions were based on district geological features along the Maine shoreline (Kelley 1987). Appendix B Table 3 lists, for both the mainland and islands, each region, from west to east, and the CMGES quadrangle within that region.

Appendix B Table 3 also lists the total amounts of each intertidal habitat by quadrangle. It is important to note that the names of the CMGES quadrangles do not necessarily represent the town boundaries with the same name. For example, it is possible to have a portion of ledge from the town of Bailey Island summed within the Orrs Island quadrangle. Therefore, without additional reference to the original maps or GIS quad, the data from the individual quadrangles should be used only loosely to refer to the geological settings of townships.

Appendix B. Table 1. A list of the seven intertidal habitats and their corresponding environments and GIS map symbols (Un id) from the Timson maps.

HABITAT	TIMSON ENVIRONMENT	MAP SYMBOL (Un Id)
Salt marsh	High salt marsh	M1
	Low salt marsh	M2
	Marsh levees	M3
	Salt pannes and ponds	M4
	Abandoned tidal channels	Cb
	Fluvial-estuarine channel	Mc
Sand beach	Sand beaches	B1
	Spit	Bs
	Swash bars	Ms
Ledge	Ledge	M
Boulder beach	Boulder beach	B4
	Boulder ramp	Br
Mixed coarse and fines	Gravel beach	B3
	Seaweed&coarse-grained flat	F2
	Sand and gravel beach	B2
	Low energy beach	B5
	Mussel bar	F3
Sand flat	Coarse-grained flat	F1
	Fan deltas	Mb
	Spillover lobes	Md
	Ebb-tidal delta	Me
	Flood-tidal deltas	Mf
	Unidentified	Mx
Mud flat	Mud flat	F
	Channel levee	F4
	Algal flat	F5
	Veneerer ramp	F6

Appendix B. Table 2. A comparison of the classification of intertidal marine environments between the current report and Brown (1993), Cowardin et al. (1979) and the Marine Geological Environments (Maine State Planning Office 1983).

Ward 1999	Brown 1993	Cowardin et al. 1979	SPO Geology Report 1983
Salt marsh			marsh levees salt pannes and ponds channels
Sand beaches	sand beaches	sand beaches	sand beach spit swash bars
Ledge	rock	rubble ledge	ledge
Boulder beaches	boulder	rubble	boulder beach boulder ramp
Mixed coarse and fines	mixed coarse and fines	gravel cobble	gravel beach seaweed and coarse-grained flat sand and gravel beach low energy beach mussel bar
Sand flat	sand flat	gravel cobble	coarse-grained flat fan deltas spillover lobes ebb-tidal delta flood-tidal deltas
Mud flat	mud flat	mud flat	mud flat channel levee algal flat veneerer ramp

Appendix B. Table 3. Total area of intertidal habitat (acres) listed by CMGE quadrangle and region from west to east.

Region	Quadrangle	Sand Beach	Mixed Flat	Boulder	Mud Flat	Sand Flat	Salt Marsh	Ledge	Total
SW	Portsmouth	0	19	0	92	110	5	13	240
SW	Isles of Shoals	0	1	2	1	1	0	86	91
SW	Kittery	13	138	34	713	48	360	150	1455
SW	Dover East	0	17	0	387	0	112	13	528
SW	York Harbor	14	19	1	278	51	433	20	817
SW	York Beach	94	30	26	10	94	11	222	488
SW	Wells	266	81	24	142	104	1697	56	2370
SW	Kennebunkport	43	58	8	230	19	180	319	857
SW	Kennebunk	0	0	0	0	0	51	2	53
SW	Biddeford	288	21	4	97	247	1097	180	1934
SW	Biddeford Pool	112	88	22	269	49	64	186	790
SW	Old Orchard Bch	46	0	0	0	0	236	0	281
SW	Prouts Neck	329	41	31	92	389	2380	172	3435
SC	Cape Elizabeth	46	34	18	0	9	5	267	380
SC	Portland West	0	27	0	1289	0	227	4	1546
SC	Portland East	97	215	47	1251	231	170	549	2560
SC	Yarmouth	19	200	0	1096	73	363	117	1868
SC	Freeport	9	232	28	2581	147	304	585	3885
SC	South Harpswell	19	120	57	92	87	16	895	1285
SC	Bailey Island	2	18	14	3	11	3	249	301
SC	Orrs Island	24	176	5	2995	20	435	1042	4696
SC	Phippsburg	29	14	5	1976	326	1682	447	4478
SC	Small Point	338	6	0	300	250	594	376	1865
SC	Brunswick	5	13	0	414	309	129	39	910
SC	Bath	0	9	0	1011	402	204	140	1766
SC	Wiscasset	0	0	0	298	0	25	12	334
SC	Westport	0	10	0	2613	0	397	404	3423
SC	Boothbay Harbor	22	59	26	460	64	690	768	2089
SC	Damariscotta	0	13	0	1087	0	703	87	1889
SC	Bristol	3	31	3	1052	8	60	247	1405
SC	Pemaquid Point	11	77	45	42	17	13	614	820
SC	New Harbor	0	1	2	9	0	0	53	66
SC	Louds Island	7	161	47	369	13	18	723	1337
SC	Monhegan	3	13	15	0	0	0	164	194
SC	Waldoboro West	1	16	0	861	1	211	150	1241
SC	Waldoboro East	1	36	0	427	3	32	182	681
SC	Friendship	28	136	2	960	103	53	1271	2552
SC	Thomaston	0	121	0	1840	10	480	223	2674
SC	Tenants Harbor	52	127	5	612	7	51	891	1745
NC	Hewett Island	51	4	0	34	0	0	311	400
NC	Rockland	154	270	221	566	87	55	446	1800

Region	Quadrangle	Sand Beach	Mixed Flat	Boulder	Mud Flat	Sand Flat	Salt Marsh	Ledge	Total
NC	Camden	20	47	77	69	4	0	132	350
NC	Matinicus	6	71	14	0	3	2	315	412
NC	Lincolnville	3	23	7	4	31	4	6	79
NC	Belfast	0	12	0	165	7	5	7	196
NC	Searsport	15	144	53	105	266	14	147	744
NC	Islesboro	6	184	80	319	83	53	551	1276
NC	Northhaven west	5	169	92	100	18	20	409	813
NC	Northhaven east	2	243	135	138	22	30	525	1095
NC	Leadbetter Isl.	11	31	20	184	1	25	641	912
NC	Vinalhaven	22	102	11	1057	1	70	1047	2310
NC	Bucksport	13	65	21	884	38	418	103	1543
NC	Castine	28	254	93	562	204	39	248	1428
NC	Penobscot	2	117	1	1155	170	61	106	1612
NC	Cape Rosier	5	147	59	422	51	78	366	1128
NC	Sargentville	16	185	173	233	141	25	368	1141
NC	Deer Isle	12	190	65	1096	142	141	621	2269
NC	Stinson Neck	3	193	90	583	2	7	915	1793
NC	Isle au Haut west	26	53	69	11	5	4	351	518
NC	Isle au Haut east	18	51	54	13	5	11	489	640
NC	Brooklin	3	216	232	680	94	56	431	1712
NC	Blue Hill	0	31	4	229	3	5	129	401
NC	Ellsworth	0	1	0	84	0	11	6	103
NC	Barlett Island	5	227	198	276	9	41	422	1179
NC	Swans Island	24	146	147	360	28	32	914	1652
NC	Johns Island	0	56	14	1	0	4	130	205
NC	Frenchboro	0	18	5	9	1	4	98	134
NC	Bass Harbor	7	179	59	324	16	73	413	1070
NC	Southwest Harbor	9	103	19	467	3	136	307	1045
NC	Seal Harbor	15	94	19	23	24	57	351	584
NC	Bar Harbor	9	297	133	429	82	15	552	1516
NC	Salsbury Cove	34	103	40	2121	3	130	439	2870
NC	Newbury Neck	0	169	54	710	15	9	396	1354
NC	Hancock	0	93	23	1226	0	111	317	1770
NC	Sullivan	0	51	7	805	28	129	115	1134
NC	Winter Harbor	22	209	27	1070	7	223	727	2285
NC	Schoodic Head	0	68	43	82	18	9	435	653
NC	Petit Manan	3	335	110	1681	69	205	902	3306
NC	Bois Bubert	21	204	90	150	39	88	660	1252
NC	Cherryfield	0	8	0	218	1	434	11	672
NC	Harrington	12	210	21	4789	49	1077	590	6748
NC	Columbia Falls	0	0	0	9	0	298	0	307
NC	Addison	1	143	22	2456	53	383	699	3755
NC	Drisko Island	2	81	27	2	36	2	373	524
NC	Great Wass Isl.	4	255	78	86	90	8	844	1365

Region	Quadrangle	Sand Beach	Mixed Flat	Boulder	Mud Flat	Sand Flat	Salt Marsh	Ledge	Total
NC	Jonesport	184	371	80	989	118	111	860	2713
NC	Whitneyville	0	28	1	806	0	127	85	1047
NC	Roque Bluffs	76	287	152	69	282	81	607	1555
NC	Machias	1	78	1	2130	29	511	197	2945
NC	Machias Bay	24	525	82	2145	328	37	559	3700
NC	Cross Island	31	58	17	24	5	16	350	502
NE	Cutler	6	79	39	132	30	30	263	579
NE	Moose River	1	28	31	57	17	7	149	291
NE	West Lubec	16	111	84	1453	123	216	649	2651
NE	Lubec	43	94	128	580	323	53	173	1394
NE	Whiting	4	29	16	769	1	106	321	1245
NE	Pembroke	0	73	41	1393	34	239	758	2538
NE	Eastport	12	442	263	1508	309	113	760	3406
NE	Robbinston	47	60	27	10	272	6	118	540
NE	Red Beach	0	14	5	42	1	2	32	95
NE	Devil's Head	5	20	2	167	68	20	81	364
NE	Calais	0	1	0	95	12	9	0	117