Salt Marsh Ecology

Salt marshes are coastal wetlands that are flooded regularly by the tides. They range in size from narrow shoreline fringes to vast meadows. Salt marshes play an integral role in improving water quality by removing contaminants, excess nutrients, and sediment washed downstream from the watershed. Acre for acre, salt marshes can produce an amount of plant biomass similar to intensively farmed cropland. This abundant plant growth helps to sustain food webs of shellfish, fish, birds, and wildlife, not only in the marshes but offshore and in surrounding terrestrial ecosystems. Winter flounder, striped bass, clams, and other species of commercial and recreational value are among the animals and plants that thrive in healthy salt marsh ecosystems.

Tidal creek near the mouth of the Mousam River and Parsons Beach in Kennebunk, Maine.

Salt marshes are found along the coasts of all five states and provinces bordering the Gulf of Maine. Ethan Nedeau

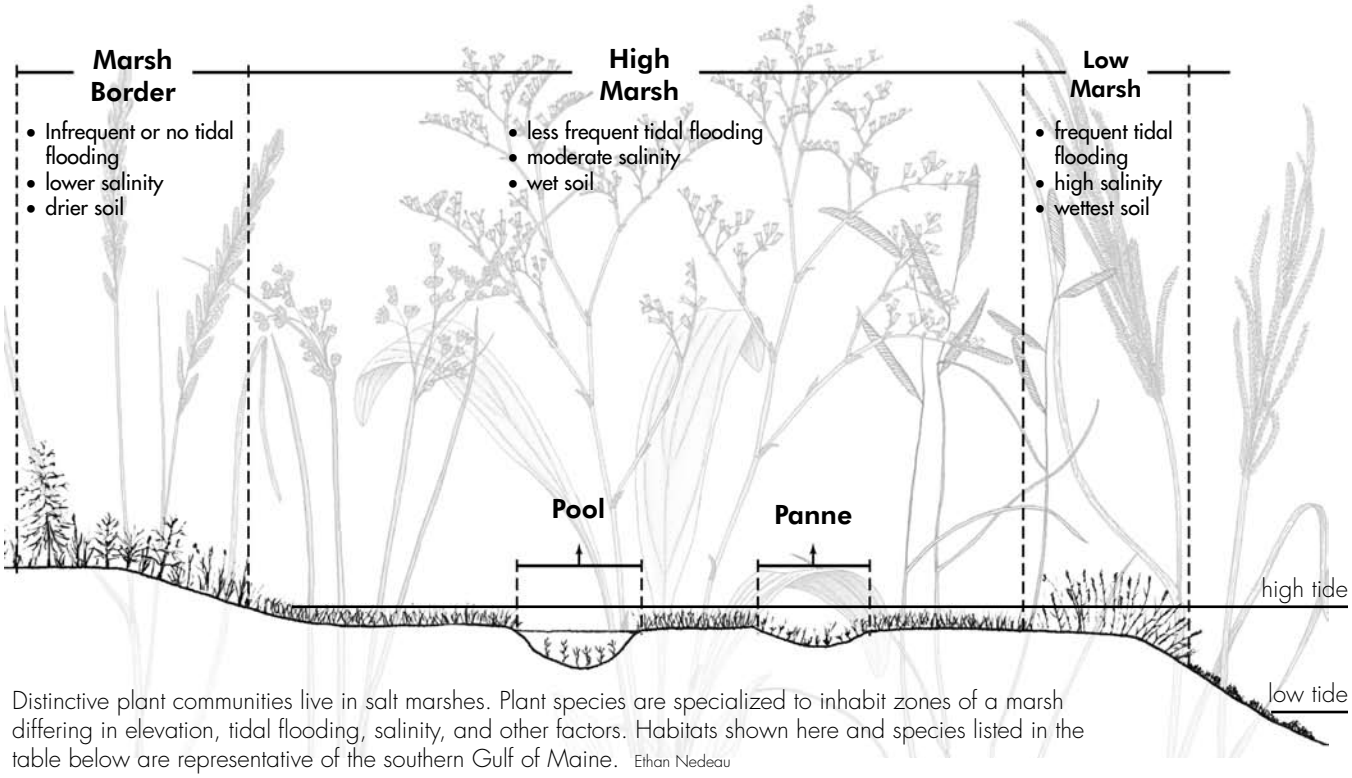
Marsh Distribution in the Gulf of Maine

A large percentage of salt marsh habitat has been destroyed in the last four centuries, but salt marshes still occur in many places along the Gulf of Maine coast. They tend to be biggest and most common in New Brunswick, Nova Scotia, and Massachusetts. The Great Marsh in northeastern Massachusetts, for example, covers some 30 square miles, making it the largest marsh in New England. Sizable marshes also exist in New Hampshire and southern Maine. The Hampton-Seabrook marsh in New Hampshire includes approximately eight of the state's ten square miles of salt marsh. The Webhannet/Little River system in Wells, Maine, encompasses six square miles, while the Scarborough Marsh near Portland is 4.2 square miles. To the north and east along the Maine coast, salt marshes tend to be smaller (Jacobson *et al.* 1987), until expansive marshes are reached along the Bay of Fundy.

Marsh Formation

Salt marshes develop over centuries in places along the coast where shelter from strong waves and currents allows sediment to accumulate. Salt marsh plants colo-

Development of surrounding land often degrades the ecological functioning of salt marshes.
Massachusetts Executive Office of Environmental Affairs/MassGIS



Distinctive plant communities live in salt marshes. Plant species are specialized to inhabit zones of a marsh differing in elevation, tidal flooding, salinity, and other factors. Habitats shown here and species listed in the table below are representative of the southern Gulf of Maine. Ethan Nedeau

Common Salt Marsh Plants

Marsh Border	High Marsh	Pool	Panne	Low Marsh
Switchgrass (*Panicum virgatum*)	Smooth cordgrass (short) (*Spartina alterniflora*)	Widgeon grass (*Ruppia maritima*)	Seaside plantain (*Plantago maritima*)	Smooth cordgrass (tall) (*Spartina alterniflora*)
Slough grass (*Spartina pectinata*)	Salt meadow hay (*Spartina patens*)		Glasswort (*Salicornia* sp.)	
Common reed (*Phragmites australis*)	Spike grass (*Distichlis spicata*)		Smooth cordgrass (*Spartina alterniflora*)	
Marsh elder (*Iva frutescens*)	Black rush (*Juncus gerardii*)		Blue-green algae	
	Sea lavender (*Limonium nashii*)			

nize the sediment because they are uniquely adapted to the wet and salty environment. Their dense stems trap even more sediment and organic matter, and gradually a foundation of peat develops. Over time, the peat accumulates, allowing the marsh to expand horizontally and vertically. On the whole, the Gulf of Maine region has fewer, smaller salt marshes than the southeastern U.S. coast because glaciers scoured the bedrock of the Gulf of Maine watershed.

Dominant Plants

Approximately thirty plant species commonly inhabit Gulf of Maine salt marshes, but the dominant plants are two closely related grasses called *Spartina alterniflora* (smooth cordgrass) and *Spartina patens* (salt meadow hay). *Spartina alterniflora* grows along the edges of creeks and channels at the low fringes of the marsh, where tides flood the peat and plants twice daily. *Spartina patens* grows in slightly elevated, interior portions of the marsh that are flooded less often, during the higher (spring) tides. Salt marshes in New Hampshire and Maine have a higher ratio of high marsh (characterized by *Spartina patens*) to low marsh (characterized by *Spartina alterniflora*) than salt marshes in southern New England (Nixon 1982).

Values of Salt Marshes

Salt marshes remove pollutants from water

River water and groundwater flowing into a salt marsh often contain sediments, excess nutrients, and toxic contaminants from land-based human activities. Salt marshes filter some of these pollutants in the following ways:

- Dense vegetation in the salt marsh slows the water, which causes suspended particles to settle, clarifying the water.
- During spring and summer, marsh plants take up nutrients that otherwise might cause algal blooms and eutrophication in coastal waters.
- Denitrification by microbes in marsh sediments removes nitrogen from the ecosystem.
- Plants and microbes remove some toxic contaminants, which eventually become incorporated into peat, resulting in long-term burial and removal from the food web.

Salt marshes have a remarkable capacity for removing nitrogen from groundwater. This function is notable because it helps to protect coastal marine ecosystems from eutrophication caused by fertilizers, septic systems, and other nitrogen sources. Unlike other habitats along the coast, salt marshes tolerate large inputs of nitrogen. Nitrogen entering a marsh as nitrate or nitrite in the groundwater can be transformed to nitrogen gas by denitrification and released to the atmosphere. Nitrogen taken up by plants eventually

Nitrogen Removal Benefits Eelgrass

Even animals and plants that do not live in salt marshes reap benefits from nitrogen removal by marsh plants. For example, research by Valiela *et al*. (2000) in Waquoit Bay, Massachusetts, provided compelling evidence that salt marshes help nearby eelgrass beds to thrive. Eelgrass beds are an important habitat for many fish and invertebrates, so nitrogen removal by salt marshes likely benefited these species. For many years, high levels of nutrients had entered Waquoit Bay from the land. Valiela *et al*. found that areas of the bay that featured large salt marshes tended to have large eelgrass beds. Areas with less salt marsh had smaller eelgrass beds. By removing nitrogen, the salt marshes apparently reduced growth of phytoplankton and seaweed, which block the sunlight needed by eelgrass. Large salt marshes did a better job of removing nitrogen than small marshes, so they had larger eelgrass beds nearby.

Waquoit Bay is located in Falmouth, Massachusetts, along the coastline of Cape Cod. Residential development in the watershed has increased the input of nitrogen to the bay.

Massachusetts Executive Office of Environmental Affairs/MassGIS

Nitrate Removal from Groundwater

Weiskel *et al*. (1996) studied ecosystem processes at Namskaket marsh on the north side of Cape Cod. Groundwater entering the marsh carried nitrate from the surrounding residential areas and a sewage treatment plant. The nitrate concentration of the groundwater was 35 µM (490 ppb). Remarkably, 44 percent was denitrified within the first 100 meters. Even when the scientists experimentally elevated the nitrate concentration to 240 to 620 µM (3.4 to 8.7 ppm), denitrification reduced that level by one third within the first 100 meters.

Key points for management

- Salt marshes remove some nitrate from groundwater, essentially providing tertiary treatment for no cost.
- By **removing excess nitrogen and preventing growth of algae**, salt marshes enhance the condition of other habitats such as eelgrass beds.
- Loss and fragmentation of salt marshes in the Gulf of Maine has **reduced capacity for nitrogen removal**, while human population and nitrogen loading have increased.

is released as organic matter in the fall or buried in peat. Because primary productivity in salt marshes tends to be limited by the amount of nitrogen that is available, when more nitrogen enters the marsh in groundwater or surface water it enhances the growth of plants and algae. Higher nitrogen levels can improve plants' food value for grazing animals (Buchsbaum *et al*. 1981), and they can also change the relative abundance of plant species and encourage invasive plants like common reed (*Phragmites australis*) (Bertness *et al*. 2002).

Salt marshes have more capability to remove nitrogen from groundwater than from tidal and surface waters. Groundwater seeps through the marsh soil and sediments, enabling plants and microbes to take up nitrogen carried by the water. In contrast, tidal and surface waters flow in channels through the marsh, having little contact with the anoxic sediments where microbes remove nitrogen. In addition, only a small proportion of tidal and surface water is absorbed by the vegetated marsh, so plants have little opportunity to take up nitrogen from the water.

Research suggests that salt marshes at Waquoit Bay promote growth of eelgrass by removing excess nitrogen.
Ben Werdmuller

Values of Salt Marshes

Salt marshes fuel coastal food webs and fisheries

Although few animals eat the live plants in a salt marsh, salt marshes contribute to the coastal food web in two major ways: export of partially decayed plant matter, or detritus, from the marsh by tidal currents and the "food web relay" that moves nutrients from the marsh into coastal waters. Salt marshes act as breadbaskets that help to support commercial and recreational fisheries in the Gulf of Maine.

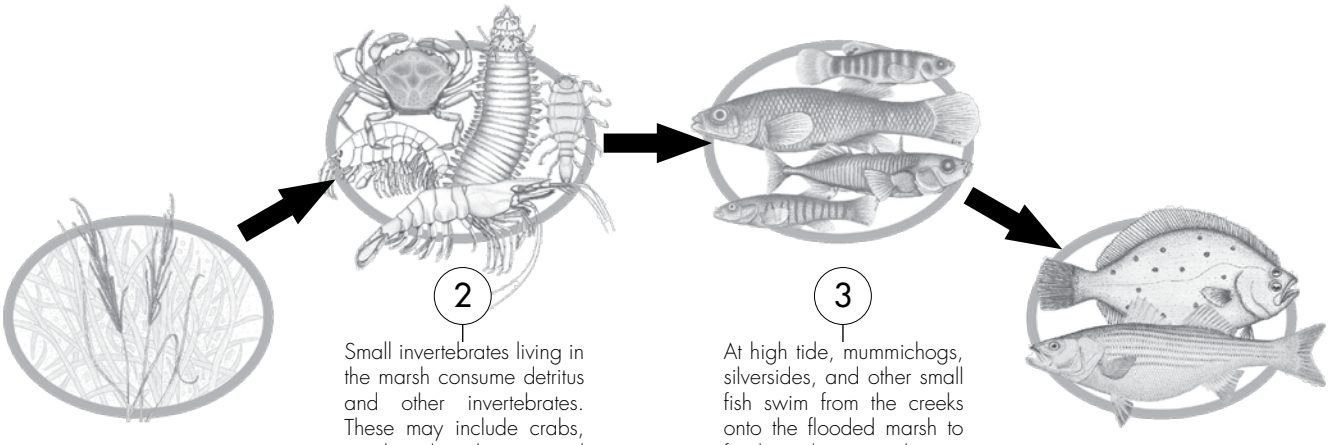
The export of waterborne detritus and dissolved nutrients from salt marshes supports the growth of phytoplankton, shellfish, and other organisms living outside marshes. Gordon (1985) showed that planktonic crustaceans in the Gulf of Maine have chemical "signatures" indicating that their nutrient supply originates in salt marshes. In the food web relay, or trophic relay (Kneib 1997), the energy captured by salt marsh plants is like the baton in a track-and-field race. Through predator-prey interactions, energy is relayed from salt marshes to the offshore food web.

A similar food web relay brings nutrients from the marsh into terrestrial food webs. Wading birds, migratory waterfowl, raptors, otters, and other animals spend part of their time feeding in salt marshes. When they defecate, die, or are eaten in the uplands, the organic matter that they obtained from the marsh enters the terrestrial food web.

Flounder Spawn in Estuaries

Winter flounder (*Pseudopleuronectes americanus*) spawn in bays and estuaries of the Gulf of Maine, and the young remain in shallow coastal waters until the age of one or two years. They feed on softshell clams, polychaetes, amphipods, isopods, and algae in the intertidal zone. As adults, the flounder migrate each summer to deeper waters. Their migratory patterns link salt marshes to offshore food webs.

Relay in the Salt Marsh Aquatic Food Web

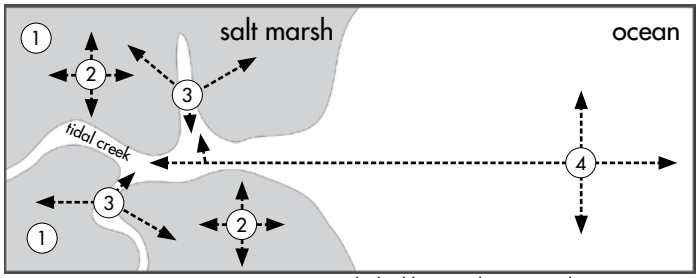


1
On the marsh surface, dead plant matter is colonized by bacteria, fungi, and protozoans, making a rich food called detritus.

2
Small invertebrates living in the marsh consume detritus and other invertebrates. These may include crabs, amphipods, shrimp, and worms.

3
At high tide, mummichogs, silversides, and other small fish swim from the creeks onto the flooded marsh to feed on detritus and invertebrates.

4
Fished species such as striped bass and winter flounder eat small fish and invertebrates in the marsh and then leave the marsh, bringing nutrients to offshore food webs.



dashed lines and arrows indicate movement

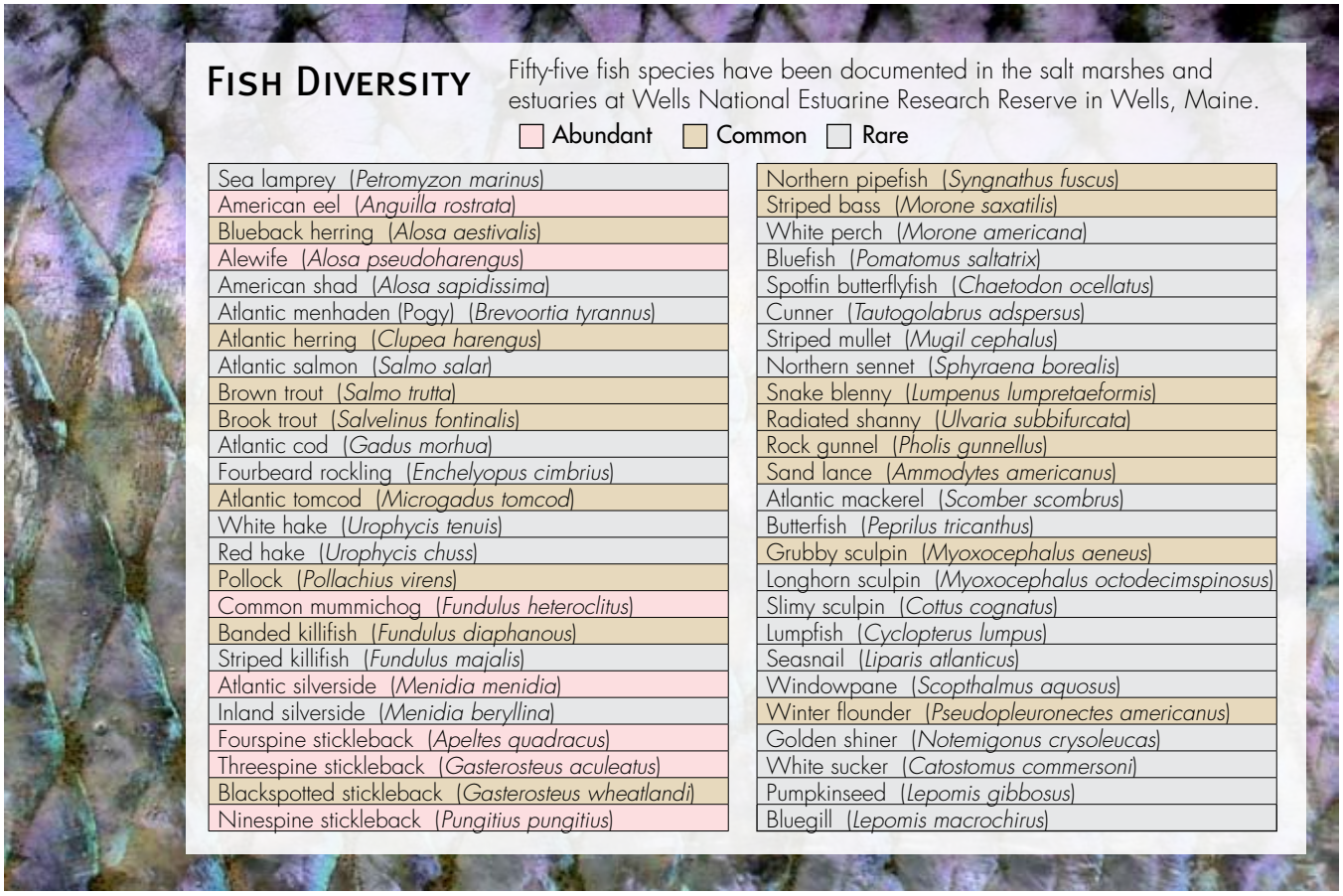
Illustrations by Ethan Nedeau except striped bass (NOAA Archives)

Silversides Migrate Offshore

The Atlantic silverside (*Menidia menidia*) is among the most abundant species in tidal creeks, salt marshes, and shallow estuaries in the Gulf of Maine. In one study, this small silver fish, along with the mummichog (*Fundulus heteroclitus*), accounted for 90 percent of fish in a Cape Cod salt marsh. Silversides spawn in shallow intertidal areas, and their eggs adhere to *Spartina alterniflora* stems. As juveniles and adults, they live and feed in salt marshes. In late fall, the silversides migrate offshore to the inner continental shelf, where they are eaten by Atlantic cod, silver hake, Atlantic mackerel, and other commercially important fish.

Key Points for Management

- There are clear links between salt marsh habitats and offshore fisheries. Protection and restoration of **salt marshes benefit commercial and recreational fisheries**.
- Undersized culverts and other structures that restrict tidal flooding of salt marshes interfere with foraging of small fish, which swim across the flooded marsh to feed on invertebrates.
- Some fish do not swim through culverts.
- Consequently, undersized culverts reduce the amount that marshes contribute to coastal food webs and fisheries.



Fish Diversity

Fifty-five fish species have been documented in the salt marshes and estuaries at Wells National Estuarine Research Reserve in Wells, Maine.

☐ Abundant ☐ Common ☐ Rare

Sea lamprey (*Petromyzon marinus*)	Northern pipefish (*Syngnathus fuscus*)
American eel (*Anguilla rostrata*)	Striped bass (*Morone saxatilis*)
Blueback herring (*Alosa aestivalis*)	White perch (*Morone americana*)
Alewife (*Alosa pseudoharengus*)	Bluefish (*Pomatomus saltatrix*)
American shad (*Alosa sapidissima*)	Spotfin butterflyfish (*Chaetodon ocellatus*)
Atlantic menhaden (Pogy) (*Brevoortia tyrannus*)	Cunner (*Tautogolabrus adspersus*)
Atlantic herring (*Clupea harengus*)	Striped mullet (*Mugil cephalus*)
Atlantic salmon (*Salmo salar*)	Northern sennet (*Sphyraena borealis*)
Brown trout (*Salmo trutta*)	Snake blenny (*Lumpenus lumpretaeformis*)
Brook trout (*Salvelinus fontinalis*)	Radiated shanny (*Ulvaria subbifurcata*)
Atlantic cod (*Gadus morhua*)	Rock gunnel (*Pholis gunnellus*)
Fourbeard rockling (*Enchelyopus cimbrius*)	Sand lance (*Ammodytes americanus*)
Atlantic tomcod (*Microgadus tomcod*)	Atlantic mackerel (*Scomber scombrus*)
White hake (*Urophycis tenuis*)	Butterfish (*Peprilus tricanthus*)
Red hake (*Urophycis chuss*)	Grubby sculpin (*Myoxocephalus aeneus*)
Pollock (*Pollachius virens*)	Longhorn sculpin (*Myoxocephalus octodecimspinosus*)
Common mummichog (*Fundulus heteroclitus*)	Slimy sculpin (*Cottus cognatus*)
Banded killifish (*Fundulus diaphanous*)	Lumpfish (*Cyclopterus lumpus*)
Striped killifish (*Fundulus majalis*)	Seasnail (*Liparis atlanticus*)
Atlantic silverside (*Menidia menidia*)	Windowpane (*Scopthalmus aquosus*)
Inland silverside (*Menidia beryllina*)	Winter flounder (*Pseudopleuronectes americanus*)
Fourspine stickleback (*Apeltes quadracus*)	Golden shiner (*Notemigonus crysoleucas*)
Threespine stickleback (*Gasterosteus aculeatus*)	White sucker (*Catostomus commersoni*)
Blackspotted stickleback (*Gasterosteus wheatlandi*)	Pumpkinseed (*Lepomis gibbosus*)
Ninespine stickleback (*Pungitius pungitius*)	Bluegill (*Lepomis macrochirus*)

Ecological Linkages

Salt marshes are connected to other habitats along the coast and offshore. They play an important role in supporting animals and plants that live outside the marsh. This aerial photograph of Harpswell Sound, Maine, indicates potential linkages.

A Salt marsh

Salt marsh fringes an inlet between a landfill (brown clearing above A) and a growing residential development. The marsh may filter contaminants, sediments, and excess nutrients running off the land before they pollute the Sound. © Peter H. Taylor

B Clam flat

Clams in these mud flats may benefit from clearer water due to the marsh's filtering of sediments, and they may eat food particles coming from the marsh. © Peter H. Taylor

C Rockweed bed

Fish in these rockweed beds may swim into the marsh to feed at high tide. Snails, crabs, and other animals may eat detritus flushed from the marsh. © Peter H. Taylor

D Eelgrass bed

Eelgrass thrives in clear water without excess nutrients, and thus may benefit from the marsh's filtering. NOAA

E Rocky bottom

The salt marsh may supply food and clean water to nearby lobstering areas. Also, striped bass and other open-water fish feed in salt marshes. © Becca Toppin

Courtesy of Maine Department of Marine Resources

F Bird staging and feeding area

Seabirds that use this island, such as the common tern, may depend directly or indirectly on the salt marsh for their food.

Andreas Solberg

G Seal haul-out and feeding area

© Peter H. Taylor

Seals feed on fish among eelgrass and rockweed beds, and rest on this rock. Swimming offshore or along the coast, they connect the salt marsh's food web to the larger marine system.

Top left: **Clapper rail** T. Leahy. bottom left: **Canada goose** USFWS, Glen Smart. right: **Snowy egret** USFWS, Ryan Hagerty.

Birds That Use Tidal Marshes

Many birds use salt marshes for feeding, nesting, and shelter. This list provides examples.

Nest in high marsh and feed in high and low marsh (*S. alterniflora*, pools, and pannes)
- Saltmarsh sharp-tailed sparrow
- Nelson's sharp-tailed sparrow
- Willet
- American black duck
- Clapper rail (rare)
- Canada goose
- Mallard

Nest in maritime shrub transition zone, feed in marsh
- Common yellowthroat
- Yellow warbler
- Eastern kingbird
- Gray catbird
- Common grackle

Nest in cattail or *Phragmites*
- Swamp sparrow
- Marsh wren
- Virginia rail
- Red-winged blackbird

Nest on offshore islands, feed in salt marsh
- Great egret
- Snowy egret
- Glossy ibis
- Great blue heron
- Little blue heron
- Common tern

Nest in cavities or next boxes, feed in salt marsh
- Tree swallow

Top: **Piping plover** USFWS, Gene Nieminen. bottom left: **Willet** USFWS, Gary Kramer. bottom right: **Least tern** USFWS, S. Maslowski.

Nest on beaches, feed in salt marshes, beaches, and mudflats
- Least tern
- Piping plover

Feed in salt marshes during migration
- Semipalmated sandpiper
- Least sandpiper
- Short-billed dowitcher
- Greater yellowlegs
- Lesser yellowlegs
- Savannah sparrow
- Eastern meadowlark
- Northern harrier

Winter in salt marshes
- Snow bunting
- Snowy owl

Use tidal creeks, bays, and mudflats
- Red-breasted merganser (fall and winter)
- Osprey
- Great blue heron
- Common loon (fall and winter)
- Semipalmated plover (migration)
- Gulls

Summary of Salt Marsh Ecological Functions

- **High primary productivity** rivals agricultural systems. Formation and accumulation of detritus fuels food webs inside and outside the marsh.
- Source of **food for shellfish and finfish**, including commercially and recreationally important species.
- **Nursery for some young fish**.
- **Filtration of water** to remove sediments, nutrients, and contaminants. **Recycling of some nutrients** in organic form to coastal food webs.
- Accumulation of peat as sea level rises, which elevates shorelines and stores carbon, two critical components to **buffer against climate change** and coastal submergence.
- **Foraging, staging, and sheltering habitat** for many bird and mammal species.
- **Protection of uplands** and **prevention of property damage**.
- **Enjoyed by people** for boating, hunting, canoeing, kayaking, hiking, sightseeing, bird watching, and the arts.
- Often used as **outdoor classrooms** for students and nature enthusiasts.
- Able to **self-maintain ecological functions** and values listed above as long as humans do not disrupt intrinsic processes.

Illustration © Barbara Harmon

Life in a Northeastern Salt Marsh

Shown above: Great blue heron...Green heron...Canada geese...Belted kingfisher...Black duck...Saltmarsh sharp-tailed sparrow...Willet...Osprey...Northern harrier...Smooth cordgrass...Salt meadow hay...Seaside lavender...Glasswort...Fiddler crab...Horseshoe crab...Periwinkle snail...Softshell clam...Ribbed mussel...Clamworm...Algae and diatoms...Zooplankton... American eel...Killifish...Atlantic silversides...Raccoon...Green darner (dragonfly)...Red fox

Boston metropolitan area, late 1990s

"…There are at present about 3240 acres of city real estate in an area that contains old Boston, Roxbury, and Back Bay…When the Puritans arrived to settle this area, there existed only 1185 acres of dry land on which to build. Four hundred eighty-five acres of the present 3240 acres were shallow water which was part marsh, part mud and sand flat, and part open water even at low tide. There was a gain of 2055 acres of dry land made by filling the marshes and lowlands."

John and Mildred Teal, 1969
From *Life and Death of the Salt Marsh*

Boston area, late 1700s