Appendix B

Wells Harbor Ecology (materials from the Wells NERR)

Chapter 8

Vegetation

Caitlin Mullan Crain

Plants are primary producers that use photosynthesis to convert light energy into carbon. Plants thus form the base of all food webs and provide essential nutrition to animals. In coastal "biogenic" habitats, the vegetation also engineers the environment, and actually creates the habitat on which other organisms depend. This is particularly apparent in coastal marshes where the plants themselves, by trapping sediments and binding the sediment with their roots, create the peat base and above-ground structure that defines the salt marsh. The plants thus function as foundation species, dominant organisms that modify the physical environment and create habitat for numerous dependent organisms. Other vegetation types in coastal systems function in similar ways, particularly seagrass beds or dune plants. Vegetation is therefore important for numerous reasons including transforming energy to food sources, increasing biodiversity, and creating habitat.

Major vegetation types in the coastal areas of Wells NERR include macroalgae, submerged aquatic vegetation, and beach dune communities, and marshes (which vary in salinity from salt to brackish to tidal freshwater). In this chapter, we will describe what these vegetative communities look like, special plant adaptations for living in coastal habitats, and important services these vegetative communities perform. We will then review important research conducted in or affiliated with Wells NERR on the various vegetative community types, giving a unique view of what is known about coastal vegetative communities of southern Maine.

Coastal Vegetation

Macroalgae

Algae, commonly known as seaweeds, are a group of non-vascular plants that depend on water for nutrient acquisition, physical support, and reproduction. Algae are therefore restricted to living in environments that are at least occasionally inundated by water. Because algae photosynthesize using light reflected through the water, most algae cannot live in dark ocean depths and thus are most common in intertidal and shallow subtidal environments. Algae are generally broken into three major divisions based on their photosynthetic pigments—red, green, and brown—which are used for identification and characterization.

Species diversity of algae is high on southern Maine coastlines, with 148 species of seaweeds recorded in coastal and estuarine environments (Mathieson *et al*. 2001). While many species can be found in this region, coastal habitats defined by algal occupants are less common. Macroalgal communities are dominant on hard substrate, particularly rocky shores. In southern Maine, the shoreline is predominantly soft sediments and macroalgae persists here on occasional hard substrates or in un-anchored forms. Hard substrates on this stretch of coast are typically man-made structures such as docks or jetties, or occasional boulders. These substrates are often colonized by large brown algae, knotted wrack, *Ascophyllum nodosum*, rockweed, *Fucus vesiculosus* or *Fucus spiralis*. These same habitats can be opportunistically occupied, particularly after disturbances or when herbivory by snails is low, by fast growing green algae *Enteromorpha intestinalis* and *Ulva lactuca*. The macroalgal communities have been well studied in their more extensive ranges on rocky shorelines, but their role here is likely very similar. Mats of large brown algae have been shown to alter local environmental conditions by providing a cool, moist habitat favored by many invertebrate species that are otherwise limited from these locations by dessication stress (Bertness *et al*. 1999). Intertidal algae provide a food source for numerous invertebrates and an anchoring site for other epiphytic algae (see kelp fronds pictured). Knotted wrack and rockweed are critical rocky shore organisms, responsible for much of the intertidal productivity and habitat provisioning of these shores. These macroalgae are harvested for packing material in the shellfish industry which can locally threaten macroalgal populations, particularly since reproductive output is relatively low and localized.

"Ecads," a type of algae that become entangled among salt marsh plants and then continue to grow, are the topic of a 2006 research project at Wells NERR. Note the PVC tubing marking a research plot, and the grey-blue algae at the base of the green Spartina alterniflora. Photo Megan Tyrrell.

These dominant brown algae can also be found growing without holdfasts in the low salt marsh community (Mathieson and Dawes 2001, pictured). Here the algae are effectively anchored by growing entangled in and around the roots and shoots of the salt marsh plants. Research has shown that both plants and algae benefit from this association as the plants are more productive, likely due to algal nutrient delivery, and the algae gain anchor sites and are less subject to desiccation (Gerard 1999).

Non-anchored macroalgae can also be found free-floating in the water column as drift algae. Most drift algae originate as attached plants that are disturbed, often resulting in altered morphology and loss of sexual reproduction. A high diversity of algal species can be found as drift algae. High nutrients in the water column, often due to human sources, can cause "blooms" of drift algae which can be quiet harmful to the marine environment, by causing low oxygen conditions, fouling beaches, impacting fisheries and altering marine communities.

Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation (SAV), commonly known as seagrass, are rooted flowering plants (angiosperms) that are specially adapted for surviving life underwater. Subtidal seagrass beds are very productive, supplying food and carbon to adjacent marine communities, and provide habitat and predator refuge to numerous associated invertebrate and fish species. Seagrass beds trap and bind sediments, preventing coastal erosion and driving geomorphology of the shoreline. Beds of eelgrass, *Zostera maritima*, were common historically in shallow coastal areas of New England, but their areal coverage has declined due to nutrient pollution, physical disturbance and disease. These communities are very important for marine health and substantial efforts have been

Kelp fronds anchored by a holdfast to a cobble. Photo Susan Bickford.

directed towards seagrass restoration projects in New England. While seagrass beds are not currently found within Wells NERR, there is some indication that the subtidal mudflats were once colonized by eelgrass (Short *et al*. 1992).

SAV can also be found in permanent ponds within salt marshes. Widgeongrass, *Ruppia martima*, is common and abundant and can tolerate the variable and at times harsh conditions of these marsh pools. Widgeongrass is a favorite and important food source for ducks and waterfowl that pause along migratory routes to fuel up in salt marsh ponds.

Dune Vegetation

Coastal dunes form above the highwater line of sandy beaches and define the terrestrial edge of these habitats. Dunes are dynamic communities that are colonized and stabilized by plants, and through succession can be transformed to more terrestrial environments or can be eroded and return to the sea. Dunes result from onshore winds that blow sand particles up the shoreline until they are deposited and stabilized, usually by wrack, at the high tide line. These "embryo" dunes are unstable and transient unless colonized by plants. Dune plants are specially adapted to these variable conditions, and primary colonizers are tolerant of dry conditions, high salinities and shifting sediments. Many of these plants have similar adaptations for dealing with high salinities and water stress as will be described in the salt marsh plants below, such as succulence, sunken stomates and curled or hairy leaves. These plants are additionally adapted to grow quickly after burial by sand.

As the dune ages, plant roots increase stability and increase organic matter, making nutrients more available. Dunes thus exhibit stages of succession that are mirrored by zonation of plants that vary in their ability to tolerate the varying physical conditions. Typical dune succession is characterized with increasing age by the foredune community, dunegrass community (pictured), dry dune slack community, shrub community and dune forest community (Nelson and Fink 1980). Each community has characteristic plants adapted to the physical conditions and facilitated by plants and their feedbacks in earlier successional stages.

The dominant plant species on foredunes of southern Maine is beach grass, *Ammophila breviluguilata*. Other plants often found in the dunes include dusty miller, *Artemesia stelleriana*, and beach pea, *Lathyrus japonicus*. Dune vegetation is responsible for stabilizing and creating the developing dune community which is an important habitat for other wildlife. Of particular importance

American beachgrass at the edge of a dune at Laudholm Beach. Photo Hannah Wilhelm.

Sea lavendar, Limonium nashii, grows in high marsh forb zones. Photo Wells NERR.

in southern Maine is provision of habitat to endangered seabirds, least terns and piping plovers.

Dune communities are present on the Laudholm Beach where the natural dune remains. However, much of the dune habitat in southern Maine has been removed due to coastal development. Loss of dunes makes shorelines less stable and removes the wave buffering capacity, making coastal habitats much more vulnerable to waves and erosion.

Salt Marsh Vegetation

Salt marshes develop in protected intertidal environments, and in southern Maine this is generally behind barrier beaches that dissipate wave energy. Vegetation in salt marshes has fairly low diversity, as few plants are adapted to tolerate the challenging physical conditions of these habitats. Inundation with salt water is stressful

Glasswort (Salicornia europaea), the reddish plant in this marsh landscape, is the most salt-tolerant plant on the marsh. It is the first colonizer of disturbed bare substrates that have high soil salinities due to evaporation in the absence of shading by plants. Photo Andrea Leonard.

for plants that have evolved in terrestrial environments. The plants that do inhabit salt marshes are halophytes (salt-tolerant plants, one of the more showy being the salt marsh aster, pictured) that can additionally tolerate waterlogging stress due to tidal flooding. Plant adaptations to salt stress include concentrating solutes in their tissues to counteract salt gradients that otherwise pull water out of the plant. Many plants have salt glands that concentrate and excrete salts onto leaf or stem surfaces and some are succulents that concentrate water in storage cells. Plant adaptations to waterlogging include shallow rooting, or even mounding (see Fogel *et al*. 2004, Crain and Bertness 2005) that enable plants to avoid anoxic sediments, and aerenchyma, hollow stems that allow air to pass from above ground into the waterlogged soils around the roots.

Figure 8-1: Common glasswort, *Salicornia europaea*, is a succulent that sequesters salt in its tissues, turns a distinctive red color in the fall, and often colonizes disturbed areas of the marsh. Drawing by Kristen Whiting-Grant.

Dominant Plant Zones

Dominant plants of New England salt marshes vary across intertidal elevations with smooth cordgrass, salt marsh hay, and black rush occupying the low, mid, and high marsh elevations respectively. These plants are most often found in monotypic (single species) stands that vary predictably with elevation. This typical zonation of plants is driven by plant tradeoffs in tolerance to physical stress versus competitive ability. For instance, the low marsh dominant, smooth cordgrass, can tolerate greater salt and waterlogging stress than the other marsh dominants, but is a poor competitor for resources in the less stressful mid and high marsh elevations. The same tradeoffs hold across the marsh platform, leading to a general rule that a species low marsh distribution is set

Aster tenufolius, the perrenial salt marsh aster, can be found near the wooded upland edge on the Webhannet marsh. Photo Ward Feurt.

by physiological stress, while upper marsh distributions are set by competition with other plants (Bertness and Ellison 1987, Bertness 1991).

In northern New England marshes, a forb panne community, not found farther south, occupies substantial area in mid-tidal elevations. This community is characterized by relatively large amounts of bare space and a high diversity of salt marsh forbs (non-grass, broad-leaved plants). Characteristic plants include seaside lavender (*Limonium nashii*), common arrowgrass (*Triglochin maritima*), seaside plantain (*Plantago maritima*), smooth cordgrass (*Spartina alterniflora*). Research at Wells NERR has discovered that high soil waterlogging makes these habitats particularly stressful and excludes the dominant marsh grasses from occupying these areas, thus providing a competitive refuge for stress tolerant forbs (Ewanchuk and Bertness 2004b). When soils are artificially drained, the forbs lose their competitive refuge and dominant marsh grasses invade and out-compete the forbs (Ewanchuk and Bertness 2004a). These findings led researchers to suggest that the lack of forb pannes in southern New England marshes may be due to the extensive ditching for mosquito control that effectively drained these marshes. This hypothesis is under further investigation. Forb pannes may also be transient features of the marsh that occur after disturbances, particularly from ice. Icing is common in southern Maine, and ice scours leave waterlogged and stressful environments occupied opportunistically by forb panne species (such as glasswort, pictured) that can slowly facilitate succession by dominant marsh grasses (Ewanchuk and Bertness 2003). One plant important in extremely waterlogged pannes, *Triglochin maritima*, can form raised root mounds, or hummocks, on which other plants live. This plant thus serves as an ecosystem engineer that alters the physical environment, thus providing habitat and enabling a plant community to persist that would otherwise be unable to live in these stressful environments (Fogel *et al*. 2004).

While salt marsh plant zonation has been well described (Fig. 8-2, Fig. 8-3), how soil nutrient patterns vary within a marsh have been less often examined. Theodose and colleagues examined soil and nutrient dynamics in three dominant zones (salt marsh hay, black rush, and mixed forbs) in salt marshes of the Wells NERR. They found that differences exist in nutrient availability across marsh zones, specifically phosphorus, salinity and soil moisture were highest in the forb zone, ammonium-nitrogen was highest in the *Juncus* zone, and plant nitrogen was greatest in the forb and patens zones (Theodose and Roths 1999). Nitrogen mineralization rates were highest in the forb zone due to differences in both substrate quality (soil organics and nutrients) and microclimate (temperature and moisture) (Theodose and Martin 2003). It is yet unknown whether these patterns in soil parameters and nutrient dynamics drive or result from vegetation zonation.

Fringing Marshes

Salt marshes not only develop in extensive meadows behind barrier beaches, but may also form fringing marshes that occupy a narrow band along an estuarine

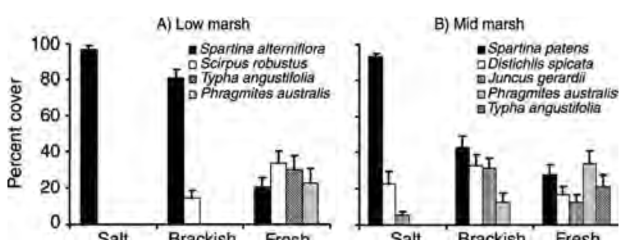

Figure 8-2: The dominant plant species varies depending on elevation. Bars show standard error (n=40) (Crain *et al.* 2004). Reprinted with permission from the Ecological Society of America.

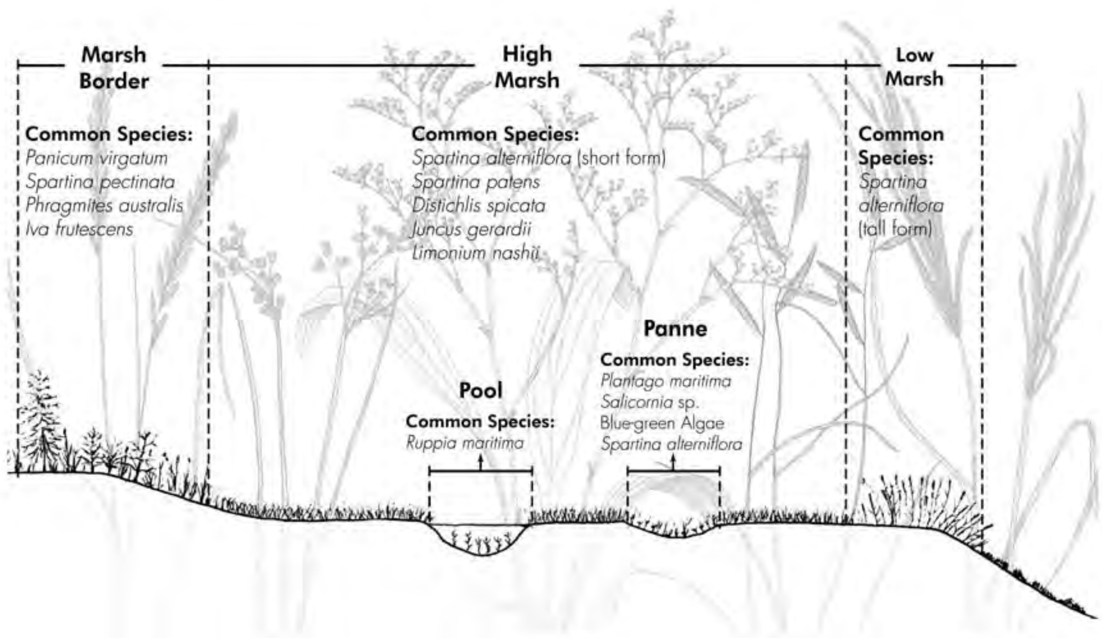

Figure 8-3: Typical zones of a salt marsh in the Gulf of Maine. In Wells NERR marshes, the low marsh zone is a narrow band located along creek and channel edges. Figure by Ethan Nedeau, Biodrawversity.

shoreline. In fact, half of the marshes in Maine are less than half an acre in size. In her doctoral dissertation, Pamela Morgan investigated how the functions in these smaller fringing marshes compare to the large meadow marshes. She found that while fringing marshes had less organic matter and plant species diversity than meadow marshes, the two marsh types had similar productivity, amount of sediment trapping, and wave buffering—indicating that fringing marshes effectively perform many important ecosystem services (Morgan 2000).

Biogeographic Patterns

Northern New England marshes at Wells NERR have served as an important comparative community in numerous studies examining biogeographic variation in species interactions. Bertness and Ewanchuk compared the direction of species interactions (positive or negative) between marsh plants and found that in marshes of southern New England, species interactions were generally positive, as plants benefited from growing with neighbors that buffered hypersalinities. However, species interactions in northern New England were generally neutral or competitive, since salinities never reached high enough levels to be overly stressful (Bertness and Ewanchuk 2002). Pennings and colleagues have investigated whether consumer-prey interactions are more intense and prey defenses better developed at lower latitudes, using salt marshes as model systems. In a series of studies using sites in Wells NERR, they found that plants in northern New England were consistently more palatable to marsh consumers than southern plants (Pennings *et al*. 2001). Differences in palatability were due to variation in plant traits including toughness, palatability of secondary compounds, and nitrogen content (Siska *et al*. 2002) and these traits remain even when grown in common environmental conditions, meaning they are hardwired and not induced by growth conditions (Salgado and Pennings 2005). These studies have been integral to understanding how important species interactions that drive community dynamics vary across latitudinal and environmental conditions.

Salt Marsh Restoration

Salt marshes are exceedingly important coastal habitats that provide many critical ecosystem services. Marshes buffer shorelines from coastal erosion and storm surges, they provide nursery and feeding grounds for fisheries and wildlife and filter upland pollutants and nutrient from marine systems. Despite their value, marshes have been heavily impacted by humans. Early colonists in New

England created berms, dikes, and tidegates to improve conditions for farming salt marsh hay. More recently road causeways and dams have lead to tidal restrictions of many coastal rivers and lead to impounded fresh marshes upriver of the restrictions. Recent efforts have been made to restore tidal flow to these choked estuaries which generally results in the return of salt marsh vegetation and associated fauna (Burdick *et al*. 1997, Boumans *et al*. 2002). However, there is concern over whether return of physical conditions associated with salt water flushing can lead to native plant reestablishment, particularly once aggressive invasives have become established (Konisky and Burdick 2004). Researchers at the Wells NERR have developed a monitoring protocol to apply consistently to tidal restoration projects in an effort to establish consensus on restoration success (Neckles *et al*. 2002, Konisky *et al*. 2006).

Low Salinity Tidal Marshes

As you travel upriver in southern Maine estuaries, marshes continue to occupy the intertidal environment, but salinities decline, eventually becoming fresh water. Across this estuarine gradient marshes vary from salt, brackish, oligohaline (low salinity), to tidal freshwater. While all of these marshes receive tides twice daily, the variation in salinity and sulfide from marine sources drive variation in plant communities. Much less research has been conducted on low salinity tidal marshes of New England; however, research at Wells NERR is beginning to address this gap. Low salinity tidal marshes harbor unique plants and animals, are the first filter for upland pollutants, are highly productive and likely offer numerous ecosystem services that we are as of yet unaware of.

Low salinity tidal marshes (pictured) have greater plant productivity and species diversity than salt marshes. Brackish marshes tend to look superficially like salt marshes, but may have additional plant species such as *Scirpus robustus*, *Schoenoplectus tabernimontenii*, *Potentilla anserina*, *Atriplex patulata*, and *Typha angustifolia*. Tidal freshwater marshes are often dominated by entirely new plant species with very high species diversity within dominant zones. Common plants include *Carex stricta*, *Juncus balticus*, *Carex crinita*, *Eleocharis* sp., *Convolvulus*

Autumn at the brackish side of Drake's Island marsh. This area was restored via the installation of a self-regulating tidegate. Cattails (Typha) are visible in the bottom left corner, indicating freshwater inputs to the upland border. Vegetative cover is dramatically different across the road on the other side of the culvert. Photo Erno Bonnebakker.

Above: a stand of invasive cattails. Below: Narrow-leaf cattail, Typha angustifolia, indicates a brackish wetland area. Photos Michele Dionne.

sepium, *Calamagrostis Canadensis*, *Spartina pectinata*, *Solidago sempervirens*, *Aster novi-belgii*, *Festuca rubra* and *Agrostis stolonifera* (see Table 8-1 for common names).

Species Distributions

Research in Rhode Island identified that the same processes driving species zonation across intertidal gradients in salt marshes drive species distribution patterns across estuarine salinity gradients. Plants found in oligohaline marshes cannot tolerate the physical conditions of salt marshes; however, salt marsh plants thrive in oligohaline marshes when native vegetation is removed but are typically competitively excluded from these habitats (Crain *et al*. 2004). Follow-up studies in southern Maine identified that the resources limiting salt marsh plants in fresh marshes vary depending on marsh zones: plants compete for nutrients in high diversity mixed plant zones and for light in *Typha angustifolia* stands (Crain in prep). Low salinity marshes are becoming increasingly dominated by *Typha* in high nutrient and disturbed areas and this causes major shifts in the community ecology of these marshes.

Studies in southern Maine estuaries identified that the limiting nutrient in coastal marshes varies across estuarine salinity gradients – salt and brackish marshes are nitrogen limited while oligohaline marshes are co-limited by nitrogen and phosphorus. Enrichment by both nutrients changes the plant composition in low salinity marshes, likely resulting in loss of species diversity given more time (Crain, in review). This study highlights the need to manage both nutrients in coastal estuaries to maintain healthy marshes of all salinities.

Some tidal freshwater marshes in Wells NERR are dominated by a tussock forming sedge, *Carex stricta*. This plant is an ecosystem engineer that alters the physical environment through the creation of mounds and subsequent retention of dead plant material, wrack, in inter-tussock spaces. All of the vegetation in these marshes is limited to living on top of the tussocks due to the suppression of vegetation by wrack in intertussock environments and additionally since tussock height provides a refuge from small mammal herbivores that forage in the intertussock areas (Crain and Bertness 2005). Tussocks thus exhibit scale-dependent inhibition where the negative effect of wrack is greatest at some distance from the tussock center, and this mechanism is responsible for generating regular spatial patterning of the vegetation (van de Koppel and Crain, in review).

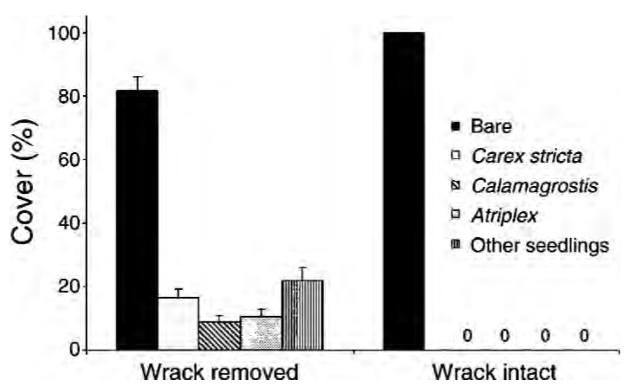

Figure 8-4: *Carex stricta* deposits wrack into inter-tussock spaces, restricting the growth of other plants. Bars show standard error (n =16) (Crain and Bertness 2005). Reprinted with permission from the Ecological Society of America.

Seed head of the common reed, Phragmites australis. Photo Andrea Leonard.

We are starting to understand the unique physical and biological factors that structure vegetative communities in low salinity tidal marshes, knowledge essential to protecting these communities from the numerous human alterations impacting these systems.

Human Impacts

Tidal restrictions change saltwater marshes to fresh impounded marshes with an accompanying shift in plant species, which often encourages invasion by monotypic stands of non-native plants.

Eutrophication, nutrient runoff from development or other watershed sources, shifts plant species interactions, reduces diversity and favors invasive plants. Both nitrogen and phosphorus are important in Wells NERR marshes. Invasive species such as *Phragmites* (see photo) and narrow-leaved cattail in the early stages of invasion are facilitated by human activity, such as altered hydrology, fill, and disturbed marsh soils.

Sea-level rise increases waterlogging of the marsh platform and also brings salt water farther upriver.

Upland development can have a direct impact on the marsh or an indirect impact through runoff of freshwater with high nutrient and sediment loads.

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Table 8-1: Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
Basidiomycota (Club Fungi)	Agaricales	Shaggy Mane Mushroom	*Coprinus comatus*
		Vermilion Hygrophorus	*Hygrophorus* sp.
		Shield Lepiota	*Lepiota clypeolaria*
	Cantharellales	Coral Mushroom	*Clavaria* sp.
		Yellow Coral Mushroom	*Clavariadelphus* sp.
	Lycoperdales	Beautiful Puffball	*Lycoperdon pulcherrimum*
		Pear-Shaped Puffball	*Lycoperdon pyriforme*
	Phallales	Earth Star	*Geaster hygrometricus*
	Polyporales	Rusty Hoof Fungus, Tinder Fungus	*Fomes fomentarius*
		Artist's Fungus	*Ganoderma applanatum*
		Cinnabar Polypore	*Polypore sanguineus*
	Tremellales	Candied Red Jelly Fungus	*Phlogiotis helvelloides*
Magnoilaphyta (Flowering Plants)	Adoxaceae	Common Elder	*Sambucus canadensis*
		Arrowwood	*Viburnum dentatum v. lucidum (V. recognitum)*
		Hobblebush	*Viburnum lantanoides (V. alnifolium)*
		Nannyberry	*Vibernum lentago*
		Wild Raisin	*Viburnum nudum v. cassinoides (V. cassinoides)*
	Amaranthaceae	Orach	*Atriplex glabriuscula*
		Spearscale	*Atriplex patula*
		Pigweed	*Chenopodium album (C. lanceolatum)*
		Narrow-Leaved Goosefoot	*Chenopodium leptophyllum*
		Coast Blite	*Chenopodium rubrum*
		Dwarf Glasswort	*Salicornia bigelovii*
		Glasswort	*Salicornia depressa(S. europaea, S. virginica)*
		Woody Glasswort	*Salicornia maritima (S. europaea* var. *prostrata)*
		Common Saltwort	*Salsola kali*
		Southern Sea-Blite	*Sueda linearis (Dondia l.)*
		White Sea-Blite	*Sueda maritima (Dondia m.)*
	Anacardiacea	Poison Ivy	*Toxicodendron radicans (Rhus radicans)*
	Apiaceae	Alexanders Or Angelica	*Angelica atropurpurea*
		Sea Coast Angelica	*Angelica lucida (Coelopleurum l.)*
		Wild Sarsaparilla	*Aralia nudicaulis*
		Common Water-Hemlock	*Cicuta maculata*
		Queen Anne's Lace	*Daucus carota*
		Marsh Pennywort	*Hydrocotyle americana*
		Dwarf Ginseng	*Panax trifolius*
		Water-Parsnip	*Sium suave*
	Apocynaceae	Tall Milkweed	*Asclepias exaltata*
		Swamp Milkweed	*Asclepias incarnata*
		Purple Milkweed	*Asclepias purpurascens*
		Common Milkweed	*Asclepias syriaca*
	Aquifoliaceae	Smooth Winterberry	*Ilex laevigata*
		Winterberry	*Ilex verticillata*
		Mountain Holly	*Nemopanthus mucronatus (N. fascicularis)*
	Araceae	Jack-In-The-Pulpit	*Arisaema triphyllulm (A. atrorubens* and *A. stewardsonii)*
		Duckweed	*Lemna* sp.
		Skunk Cabbage	*Symplocarpus foetidus (Spathyema f.)*
	Asteraceae	Yarrow	*Achillea millefolium*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Common Ragweed	*Ambrosia artemisiifolia*
		Pearly Everlasting	*Anaphalis margaritacea*
		Smaller Pussytoes	*Antennaria howellii (A. h.* ssp. *neodioica)*
		Plantain-Leaved Pussytoes	*Antennaria plantaginifolia*
		Common Burdock	*Arctium minus (Lappa minor)*
		Canadian Wormwood	*Artemisia campestris* ssp. *caudata (A. caudata)*
		Dusty Miller	*Artemisia stellariana*
		White Wood Aster	*Aster divaricatus (Eurybia diverticata)*
		Bushy Aster	*Aster dumosus*
		Arrow-Leaved Aster	*Aster sagittifolius*
		Perennial Salt marsh Aster	*Aster tenuifolius*
		Blake's Aster	*Aster x blakei*
		Groundsel Tree	*Baccharis halimifolia*
		Purple Stem Beggar Ticks	*Bidens connata*
		Devil's Beggar Ticks	*Bidens frondosa*
		Canada Thistle	*Cirsium arvense*
		Pasture Thistle	*Cirsium pumilum*
		Lance-Leaved Coreopsis	*Coreopsis lanceolata*
		Smooth Hawksbeard	*Crepis capillaris*
		Flat-Topped White Aster	*Doellingeria umbellata (Aster umbellatus)*
		Pilewort	*Erechtites hieraciifolia*
		Daisy Fleabane	*Erigeron anuus*
		Rough Fleabane	*Erigeron strigosus*
		Three-Nerved Joe-Pye Weed	*Eupatorium dubium*
		Spotted Joe-Pye Weed	*Eupatorium maculatum*
		Boneset	*Eupatorium perfoliatum*
		Grass-Leaved Goldenrod	*Euthamia graminifolia (Solidago g.)*
		Slender-Leaved Goldenrod	*Euthamia tenuifolia (Solidago t.)*
		Low Cudweed	*Gnaphalium uliginosum*
		Orange Hawkweed	*Hieracium auranticum*
		Yellow Hawkweed	*Hieracium caespitosum (H. pratense)*
		Canada Hawkweed	*Hieracium canadense*
		Mouse Ear Hawkweed	*Hieracium pilosella*
		Mouse Ear Hawkweed	*Hieracium x flagellare*
		Stiff Aster	*Ionactis linariifolius (Aster liariifolius)*
		Cynthia	*Krigia biflora*
		Virginia Dwarf-Dandelion	*Krigia virginica*
		Tall Blue Lettuce	*Lactuca biennis (L. spicata)*
		Fall-Dandelion	*Leontodon autumnalis*
		Ox-Eye Daisy	*Leucanthemum vulgare (Chrysanthemum leucanthemum)*
		Northern Blazing Star	*Liatris scariosa v. novae-angliae (L. borealis)*
		Whorled Aster	*Oclemena acuminata (Aster acuminatus)*
		Gall Of The Earth	*Prenanthes trifoliolata*
		Fragrant Cudweed	*Pseudognaphalium obtusifolium (Gnaphalium o.)*
		Clammy Cudweed	*Pseudognaphalium viscosum (Gnapha-lium macounii.)*
		Black-Eyed Susan	*Rudbeckia hirta (R. serotina)*
		Forest Goldenrod	*Soldiago arguta*
		Silverrod	*Solidago bicolor*
		Canada Goldenrod	*Solidago canadensis*
		Smooth Goldenrod	*Solidago gigantea*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Early Goldenrod	*Solidago juncea*
		Gray Goldenrod	*Solidago nemoralis*
		Rough-Leaved Goldenrod	*Solidago patula*
		Downy Goldenrod	*Solidago puberula*
		Rough-Stemmed Goldenrod	*Solidago rugosa*
		Seaside Goldenrod	*Solidago sempervirens*
		Elm-Leaved Goldenrod	*Solidago ulmifolia*
		Field Sow-Thistle	*Sonchus arvensis*
		Purple-Stemmed Aster	*Symphyotrichum puniceum (Aster puniceus)*
		Heart-Leaved Aster	*Symphyotrichum cordifolium (Aster cordifolius)*
		Calico Aster	*Symphyotrichum lateriflorum (Aster lateriflorus)*
		New England Aster	*Symphyotrichum novae-angliae (Aster novae-angilae)*
		New York Aster	*Symphyotrichum novi-belgii (Aster novi-belgii)*
		Dandelion	*Taraxacum officinale (T. latilobum)*
		Common Cocklebur	*Xanthium strumarium v. canadense (X. echinatum)*
	Balsaminaceae	Orange Touch-Me-Not	*Impatiens capensis (I. Biflora)*
	Berberidacea	American Barberry	*Berberis canadensis*
		Japanese Barberry	*Berberis thunbergii*
		Common Barberry	*Berberis vulgaris*
		Blue Cohosh	*Caulophyllum thalictroides*
	Betulaceae	Speckled Alder	*Alnus incana* ssp. *rugosa (A. rugosa)*
		Yellow Birch	*Betula alleghaniensis (B. lutea)*
		Paper Or White Birch	*Betula papyrifera*
		Gray Birch	*Betula populifolia*
		Beaked Hazelnut	*Corylus cornuta*
	Brassicaceae	Yellow Rocket	*Barbarea vulgaris (B. barbarea)*
		Hoary Alyssum	*Berteroa incana*
		Field Mustard, Bird's Rape	*Brassica rapa*
		Sea Rocket	*Cakile edentula*
		Shepherd's Purse	*Capsella bursa-pastoris (Bursa b.)*
		Cuckoo Flower	*Cardamine pratensis*
		Whitlow Grass	*Draba verna*
		Wormseed-Mustard	*Erysimum cheiranthoides (Cheirinia c.)*
		Wild Radish	*Raphanus raphanistrum*
		Watercress	*Rorippa nasturtium-aquaticum (Nasturtium officinale)*
		Hedge-Mustard	*Sisymbrium officinale (Erysimum o.)*
	Campanulaceae	Indian-Tobacco	*Lobelia inflata*
	Caprifoliaceae	Bush-Honeysuckle	*Diervilla lonicera*
		Fly Honeysuckle	*Lonicera canadensis*
		Japanese Honeysuckle	*Lonicera japonica*
		Tatarian Honeysuckle	*Lonicera tatarica*
		Mountain Fly Honeysuckle	*Lonicera villosa*
		Pink Honeysuckle	*Lonicera x bella*
	Caryophyllaceae	Thyme-Leaved Sandwort	*Arenaria serphyllifolia*
		Field Chickweed	*Cerastium arvense*
		Sea-Beach Sandwort	*Honckenya peploides* ssp. *robusta (Arenaria p.)*
		Ragged Robin	*Lychnis flos-cuculi*
		Grove Sandwort	*Moehringia lateriflora (Arenaria l.)*
		Bouncing Bet	*Saponaria officinalis*
		White Campion	*Silene latifolia* spp. *Alba (Lychnis alba)*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Night-Flowering Catchfly	*Silene noctiflora*
		Salt Marsh Sand Spurrey	*Spergularia salina (S. marina)*
		Common Stichwort	*Stellaria graminea (Alsine g.)*
		Common Chickweed	*Stellaria media (Alsine m.)*
	Celastraceae	Oriental Bittersweet	*Celastrus orbiculata*
	Cistaceae	Frostweed	*Helianthemum canadense (Crocanthemum c.)*
		Beach Heather	*Hudsonia tomentosa*
		Seaside Pinweed	*Lechea maritima*
	Clusiaceae	Pale St.Johnswort	*Hypericum ellipticum*
		Orange-Grass	*Hypericum gentianoides*
		Common St.Johnswort	*Hypericum perforatum*
		Spotted St. Johnswort	*Hypericum punctatum*
		Marsh St.Johnswort	*Triadenum virginicum (Hypericum v.)*
	Convallarianceae	Canada Mayflower	*Maianthemum canadense (Uniflium c.)*
		Star-Flowered False Solomon's Seal	*Maianthemum stellatum (Smilacina stellata)*
		Solomon's Seal	*Polygonatum pubescens*
		Hedge Bindweed	*Calystegia sepium (Convovulvus s.)*
		Common Dodder	*Cuscuta gronovii*
	Cornaceae	Silky Dogwood	*Cornus anomum*
		Bunchberry	*Cornus canadensis (Chamaepericlymenum canadense)*
	Crassulaceae	Garden Orpine	*Sedum telephium (S. purpureum)*
	Cucurbitaceae	Bur Cucumber	*Echinocystis lobata (Micrampelis l.)*
	Cupressaceae	Old Field Juniper	*Juniperus communis v. depressa*
		Red Cedar	*Juniperus virginiana*
	Cyperaceae	Salt marsh Bulrush	*Bolboschoenus maritimus* spp. *Paludosus (Scirpus m.)*
		Salt marsh Bulrush	*Bolboschoenus robustus (Scirpus r.)*
		Button Sedge	*Carex bullata*
		Fringed Sedge	*Carex crinita*
		White-Edged Sedge	*Carex debilis*
		Star Sedge	*Carex echinata (C. angustior)*
		Long Sedge	*Carex folliculata*
		Marsh Straw Sedge	*Carex hormathodes (C. straminea)*
		Interior Sedge	*Carex interior*
		Sedge	*Carex intumescens*
		Hop Sedge	*Carex lupilina*
		Sallow Sedge	*Carex lurida*
		Sedge	*Carex paleacea*
		Pointed Broom Sedge	*Carex scoparia*
		Seabeach Sedge	*Carex silicea*
		Tussock Sedge	*Carex stricta*
		Sedge	*Carex swanii*
		Sedge	*Carex tenera*
		Three Seeded Sedge	*Carex trisperma*
		Sedge	*Cyperus diandrus*
		Slender Cyperus Sedge	*Cyperus lupulinus* spp. *Macilentus (C. filiculmis)*
		Three-Way Sedge	*Dulichium arundinaceum*
		Spike-Rush	*Eleocharis halophila (E. uniglumis)*
		Creeping Spike-Rush	*Eleocharis palustris*
		Tawny Cotton Grass	*Eriophorum virginicum*
		Clustered Beak Rush	*Rhynchospora glomerata*
		Great Bullrush	*Schoenoplectus acutus (Scirpus a.)*
		Chair-Maker's-Rush	*Schoenoplectus pungens (Scirpus americanus)*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Softstem Bullrush	*Schoenoplectus tabernaemontanii (Scirpus validus)*
		Black Bullrush	*Scirpus atrovirens*
		Wool-Grass	*Scirpus cyperinus*
	Droseraceae	Round-Leaved Susndew	*Drosera rotundifolia*
	Equisetaceae	Field Horsetail	*Equisetum arvense*
		Water Horsetail	*Equisetum fluviatile*
		Meadow Horsetail	*Equisetum pratense*
		Woodland Horsetail	*Equisitum sylvaticum*
	Ericaceae	Bearberry	*Arctostaphylos uva-ursi*
		Leatherleaf	*Chamaedaphne calyculata*
		Broom Crowberry	*Corema conradii*
		Mayflower	*Epigaea repens*
		Wintergreen	*Gaultheria procumbens*
		Black Huckleberry	*Gaylussacia baccata*
		Dwarf Huckleberry	*Gaylussacia dumosa*
		Sheep Laurel	*Kalmia angustifolia*
		Maleberry	*Lyonia ligustrina (Xolisma l.)*
		Indian Pipe	*Monotropa uniflora*
		Round-Leaved Pyrola	*Pyrola americana (P. rotundifolia)*
		Rhodora	*Rhododendron canadense (Rhodora canadensis)*
		Lowbush Blueberry	*Vaccinium angustifolium*
		High-Bush Blueberry	*Vaccinium corymbosum (V. atrococcum)*
		American Cranberry	*Vaccinium macrocarpon*
		Velvet-Leaved Blueberry	*Vaccinium myrtilloides (V. canadense)*
		Small Cranberry	*Vaccinium oxycoccos*
	Euphorbiaceae	Seaside Spurge	*Chamaesyce polygonifolia (Euphorbia p.)*
	Fabaceae	Beach-Pea	*Lathyrus japonicus*
		Lupine	*Lupinus polyphyllus*
		Alfalfa	*Medicago sativa*
		Rabbit-Foot Clover	*Trifolium arvense*
		Yellow Clover, Palmate Hop Clover	*Trifolium aureum (T. agrarium)*
		Little Hop Clover	*Trifolium dubium*
		Alsike Clover	*Trifolium hybridum*
		Red Clover	*Trifolium pratense*
		White Clover	*Trifolium repens*
		Cow Vetch	*Vicia cracca*
		White Oak	*Quercus alba*
		Red Oak	*Quercus rubra (Q. borealis)*
	Gentianaceae	Yellow Bartonia	*Bartonia virginica*
	Geraniaceae	Bicknell's Wild Geranium	*Geranium bicknellii*
		Wild Geranium	*Geranium maculatum*
	Grossulariaceae	Bristly Gooseberry	*Ribes hirtellum*
	Hamamelidaceae	Witch-Hazel	*Hamamelis virginiana*
	Iridaceae	Slender Blue Flag	*Iris prismatica*
		Northern Blue Flag	*Iris versicolor*
		Blue-Eyed Grass	*Sisyrinchium montanum*
	Juglandaceae	Shagbark Hickory	*Carya ovata*
	Juncacaee	Sharp-Fruited Rush	*Juncus acuminatus*
		Wire Rush	*Juncus articus v. balticus (Juncus articus v. littoralis)*
		Canada Rush	*Juncus canadensis*
		Soft Rush	*Juncus effusus*
		Black Grass	*Juncus gerardii*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Greene's Rush	*Juncus greenei*
		Grass-Leaved Rush	*Juncus marginatus*
		Path Rush	*Juncus tenuis*
	Juncaginaceae	Seaside Arrowgrass	*Triglochin maritimum*
	Lamiaceae	Hairy Wood Mint	*Blephilia hirsuta*
		American Water-Horehound	*Lycopus americanus*
		Northern Water-Horehound	*Lycopus uniflorus*
		Virginia Water-Horehound	*Lycopus virginicus*
		Wild Mint	*Mentha arvensis*
		Heal-All	*Prunella vulgaris*
		Marsh Skullcap	*Scutellaria galericulata (S. epilobiifolia)*
		Mad Dog Skullcap	*Scutellaria laterifolia*
		American Germander	*Teucrium canadense*
		Blue Curls	*Trichostema dichotomum*
	Lauraceae	Sassafras	*Sassifras albidum*
	Liliaceae	Trout Lily	*Erythronium americanum*
		Wood Lily	*Lilium philadelphicum (L. tigrinum)*
		Indian Cucumberroot	*Medeola virginiana*
	Linaceae	Common Flax	*Linum usitatissimum*
	Lycopodiaceae	Northern Running-Pine	*Diphrasiastrum complanatum (Lycopodium c.)*
		Shining Club-Moss	*Huperzia lucidula (Lycopodium lucidulum)*
		Bristly Club-Moss	*Lycopodium annotinum*
		Ground-Pine	*Lycopodium obscurum*
	Melanthiaceae	Indian Poke , False Hellebore	*Veratrum viride*
	Myricaceae	Sweetfern	*Comptonia peregrina (Myrica aspleniifolia)*
		Sweet Gale	*Myrica gale*
		Bayberry	*Myrica pensylvanica*
	Oleaceae	White Ash	*Fraxinus americana*
		Black Ash	*Fraxinus nigra*
		Lilac	*Syringa vulgaris*
	Onagraceae	Fireweed	*Epilobium angustifolium (Chamae-nerion angustifolium)*
		American Willow-Herb	*Epilobium ciliatum*
		Narrow-Leaved Willowherb	*Epilobium leptophyllum*
		Common Evening-Primrose	*Oenothera biennis (O. muricata)*
		Small-Flowered Evening-Primrose	*Oenothera parviflora (O. cruciata)*
	Orchidaceae	Arethusa	*Arethusa bulbosa*
		Grass Pink	*Calopogon tuberosus (C.puchellus)*
		Early Coralroot	*Corallorhiza trifida*
		Pink Ladys-Slipper	*Cypripedium acaule (Frissipes acaulis)*
		Green Woodland Orchid	*Plantanthera clavellata (Habenaria c.)*
		Pale Green Orchid	*Plantanthera flava (Habenaria f.)*
		Ragged Orchid	*Plantanthera lacera (Habenaria l.)*
		Small Purple Fringed Orchid	*Plantanthera psycodes (Habenaria p.)*
		Rose Pogonia	*Pogonia ophioglossoides*
		Nodding Ladies Tresses	*Spiranthes cernua (Ibidium cenuum)*
	Orobanchaceae	Seaside Gerardia	*Agalinus maritima (Gerardia m.)*
		Purple Gerardia	*Agalinus pauperacula (Agalinus purpurea)*
		Cowwheat	*Melampyrum lineare*
		Wood-Betony	*Pedicularis canadensis*
		Yellow Rattle	*Rhinanthus minor (R. crista-galli)*
	Oxalidaceae	Common Wood Sorrel	*Oxalis montana (O. acetosella)*
		Common Yellow Wood-Sorrel	*Oxalis stricta (O. europaea)*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
	Plumbaginaceae	Sea Lavender	*Limonium carolinianum (L. nashii)*
	Poaceae	Rhode Island Bentgrass	*Agrostis capillaris (A. tenuis)*
		Redtop	*Agrostis gigantea (A. alba)*
		Autumn Bentgrass	*Agrostis perennans*
		Hairgrass	*Agrostis scabra*
		Beach Grass	*Ammophila breviligulata*
		Sweet Vernal Grass	*Anthoxanthum odoratum*
		Long-Awned Wood-Grass	*Brachyelytrum septentrionale (B. erectum)*
		Canada Blue-Joint	*Calamagrostis canadensis*
		Small Reedgrass	*Calamagrostis cinnoides*
		Orchard Grass	*Dactylis glomerata*
		Wavy Hairgrass	*Deschampsia flexuosa*
		Spike Grass	*Distilchis spicata*
		Witch Or Quack Grass	*Elymus repens (Elytrigia r.)*
		Sheep Fescue	*Festuca ovina*
		Red Fescue	*Festuca rubra*
		Rattlesnake Grass	*Glyceria canadensis (Panicularia c.)*
		Fowl Meadowgrass	*Glyceria striata (G. nervata)*
		Sweetgrass	*Hierochloe odorata*
		American Dunegrass	*Leymus mollis (Elymus arenarius)*
		Marsh Muhly	*Muhlenbergia glomerata (M. setosa)*
		Wooly Panic Grass	*Panicum acuminatum (Dichanthelium a.)*
		Witchgrass	*Panicum capillare*
		Starved Panic Grass	*Panicum depauperatum (Dichanthelium d.)*
		Panic Grass	*Panicum longifolium*
		Switchgrass	*Panicum virgatum v. spissum*
		Reed Canarygrass	*Phalaris arundinacea*
		Timothy	*Phleum pratense*
		Common Reed	*Phragmites australis (P. communis)*
		Canada Bluegrass	*Poa compressa*
		Fowl Meadowgrass	*Poa palustris (P. triflora)*
		Seaside Alkali-Grass	*Puccinellia maritima*
		Poor Grass	*Puccinellia tenella (P. paupercula)*
		Little Bluestem	*Schizachrium scoparium (Andropogon scoparius)*
		Knotroot Bristlegrass	*Setaria geniculata*
		Salt marsh Cordgrass	*Spartina alterniflora*
		Salt Hay	*Spartina patens*
		Fresh Water Cordgrass	*Spartina pectinata*
		Foxtail	*Setaria pumila (S. glauca)*
	Polygalaceae	Fringed Polygala, Gaywings	*Polygala paucifolia*
		Blood Milkwort	*Polygala sanguinea (P. viridescens)*
	Polygonaceae	Climbing False Buckwheat	*Fallopia scandens (Polygonum s.)*
		Halberd-Leaved Tearthumb	*Persicaria arifolia (Polygonum arifolium)*
		Common Smartweed	*Persicaria hydropiper (Polygonum h.)*
		Dock-Leaved Smartweed	*Persicaria lapthifolia (Polygonum lapthifolium)*
		Pennsylvania Smartweed	*Persicaria pensylvanica (Polygonum pensylvanicum)*
		Arrow-Leaved Tearthumb	*Persicaria sagittata (Polygonum sagittatum)*
		Jointweed	*Polygonella articulata*
		Prostrate Knotweed	*Polygonum aviculare*
		Sheep Sorrel	*Rumex acetosella*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Curly Dock	*Rumex crispus*
		Marsh Fern	*Thelypteris palustris v. pubescens (Dryopteris thelypteris v. p.)*
	Portulacaceae	Carolina Spring Beauty	*Claytonia caroliniana*
	Potomogetonaceae	Wigeon-Grass	*Ruppia maritima*
	Primulaceae	Sea Milkwort	*Glaux maritima*
		Whorled Loosestrife	*Lysimachia quadrifolia*
		Swamp Candles	*Lysimachia terrestris*
		Starflower	*Trientalis borealis (T. americana)*
	Ranunculaceae	Wood Anemone	*Anemone quinquefolia*
		Garden Columbine	*Aquilegia vulgaris*
		Virgin's Bower	*Clematis virginiana*
		Goldthread	*Coptis trifolia (C. groenlandica)*
		Common Buttercup	*Ranunculus acris*
		Seaside Crowfoot	*Ranunculus cymbalaria*
		Cursed Crowfoot	*Ranunculus sceleratus*
		Tall Meadowrue	*Thalictrum pubescens (T. polygamum)*
	Rosaceae	Downy Serviceberry	*Amelanchier arborea*
		Serviceberry	*Amelanchier arborea v. laevis*
		Eastern Serviceberry	*Amelanchier canadensis*
		Silverweed	*Argentina anserina (Potentilla a.)*
		Marsh-Potentilla	*Comarum palustre (Potentilla palustris)*
		Hawthorn	*Crategus* sp.
		Rattlebox	*Crotalaria sagittalis*
		Woodland Strawberry	*Fragaria vesca*
		Wild Strawberry	*Fragaria virginiana*
		Water Avens	*Geum rivale*
		Wild Apple	*Malus sylvestris (Pyrus s.)*
		Red Chokeberry	*Photinia arbutafolia (Pyrus a.)*
		Black Chokeberry	*Photinia melanocarpa (Pyrus m.)*
		Purple Chokeberry	*Photinia x floribunda (Pyrus f.)*
		Silvery Cinquefoil	*Potentilla argentea*
		Running Cinquefoil	*Potentilla canadensis (P. pumila)*
		Rough Cinquefoil	*Potentilla norvegica (P. monspeliensis)*
		Rough-Fruited Cinquefoil	*Potentilla recta*
		Old-Field Cinquefoil	*Potentilla simplex*
		Beach Plum	*Prunus maritima*
		Pin Or Fire Cherry	*Prunus pensylvanica*
		Sand Cherry	*Prunus pumila (P. p. v. susquehanae)*
		Black Cherry	*Prunus serotina*
		Chokecherry	*Prunus virginiana*
		Smooth Rose	*Rosa blanda*
		Pasture Rose	*Rosa carolina*
		Multiflora Rose	*Rosa multiflora*
		Bristly Rose	*Rosa nitida*
		Swamp Rose	*Rosa palustris*
		Rugosa Rose	*Rosa rugosa*
		Virginia Rose	*Rosa virginiana*
		Common Blackberry	*Rubus allegheniensis*
		Dewdrop	*Rubus dalibarda (Dalibarda repens)*
		Prickly Dewberry	*Rubus flagellaris*
		Swamp Dewberry	*Rubus hispidus*
		Red Raspberry	*Rubus idaeus*
		Black Raspberry	*Rubus occidentalis*
		Dwarf Raspberry	*Rubus pubescens*
		Three-Toothed Cinquefoil	*Sibbaldiopsis tridentata (Potentilla t.)*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Meadowsweet	*Spiraea alba v. latifolia (S. latifolia)*
		Steeplebush	*Spiraea tomentosa*
	Rubiaceae	White Bedstraw	*Galium mollugo (G. erectum)*
		Marsh Bedstraw	*Galium palustre*
		Bluets	*Houstonia caerulea (Hedyotis c.)*
		Partridgeberry	*Mitchella repens*
	Salicaceae	Quaking Aspen	*Populus tremuloides*
		Pussy Willow	*Salix discolor*
	Santalaceae	Bastard Toadflax	*Comandra umbellata (C. richardsiana)*
	Sapindaceae	Box Elder	*Acer negundo*
		Moosewood	*Acer pensylvanicum*
		Norway Maple	*Acer platanoides*
		Red Maple	*Acer rubrum*
	Scrophulariaceae	Common Mullein	*Verbascum thapsus*
	Smilacaceae	Carrion Flower	*Smilax herbacea (Nemexia h.)*
	Solnaceae	Bittersweet Nightshade	*Solanum dulcamara*
	Ttrilliaceae	Nodding Trillium	*Trillium cernuum*
	Typhaceae	Narrow-Leaved Cat-Tail	*Typha angustifolia*
		Common Cat-Tail	*Typha latifolia*
	Ulnaceae	Elm	*Ulmus* sp.
	Uvulariaceae	Clintonia	*Clintonia borealis*
		Wild Oats	*Uvularia sessilifolia*
	Verbenaceae	White Vervain	*Verbena utricifolia*
	Veronicaceae	White Turtlehead	*Chelone glabra*
		Butter And Eggs	*Linaria vulgaris (L. linaria)*
		Seaside Plantain	*Plantago maritima v. juncoides (P. juncoides)*
		English Plantain	*Plantago lanceolata (P. altissima)*
		Common Plantain	*Plantago major*
		Long-Leaved Speedwell	*Veronica longifolia*
		Commonn Speedwell	*Veronica officinalis*
		Thyme-Leaved Speedwell	*Veronica serpyllifolia*
	Violaceae	Common Blue Violet	*Viola affinis (V. papilionacea)*
		Marsh Blue Violet	*Viola cucullata (V. obliqua)*
		Wild White Violet	*Viola macloskeyi* ssp. *pallens (V. pallens)*
		Round-Leaved Violet	*Viola rotundifolia*
		Arrowhead Violet	*Viola sagittata (V. s. v. ovata)*
		Dooryard Violet	*Viola sororia (V. septentrionalis)*
	Vitaceae	Virginia Creeper	*Parthenocissus quinquefolia*
Coniferophyta (Conifers)	Pinaceae	Balsam Fir	*Abies balsamea*
		American Larch	*Larix laricina*
		Red Spruce	*Picea rubens*
		Red Pine	*Pinus resinosa*
		Pitch Pine	*Pinus rigida*
		White Pine	*Pinus strobus*
		Hemlock	*Tsuga canadensis*
Pteridophyta (Ferns)	Polypodiaceae	Lady Fern	*Athyrium filix-femina v. angustum*
		Hay-Scented Fern	*Dennstaedtia punctilobula*
		Spinulose Wood-Fern	*Dryopteris carthusiana (D. spinulosa)*
		Crested Fern	*Dryopteris cristata*
		Marginal Fern	*Dryopteris marginalis*
		Oak Fern	*Gymnocarpium dryopteris*
		Ostrich Fern	*Matteuccia struthiopteris v. pensylvanica*
		Sensitive Fern	*Onoclea sensibilis*

Table 8-1 (continued): Plants, fungi and algae found at Wells NERR.

Division	Order	Common Name	Scientific Name
		Long Beech Fern	*Phegopteris connectilus (Dryopteris phegopteris)*
		Bracken	*Pteridium aquilinum*
		New York Fern	*Thelypteris noveboracensis (Dryopteris n.)*
	Osmundaceae	Royal Fern	*Osmunda regalis (O. spectibilis)*
		Cinnamon Fern	*Osmunda cinnamomea*
		Interrupted Fern	*Osmunda claytonia*
Chrysophyta (Golden-brown Algae)	Chrysophyceae	Dictyochaceae	*Dictyocha* sp.
Pyrrophycophyta (Dinoflagellates)	Dinophyceae	Goniodomataceae	*Alexandrium tamarense*
		Ceratiaceae	*Ceratium fusus*
			Ceratium fusus
			Ceratium longipes
			Ceratium longpipes
		Gonyaulacaceae	*Gonyaulax spinifera*
		Calciodinellaceae	*Scrippsiella* sp.
		Dinophysiaceae	*Dinophysis acuminata*
			Dinophysis acuminata
			Dinophysis norvegica
			Dinophysis norvegica
		Gymnodiniaceae	*Gymnodinium* sp.
		Protoperidinaceae	*Protoperidinium* sp.
	Prorocentrales	Prorocentrum	*Prorocentrum micans*
Bacillariophyta (Diatoms)	Coscinodiscophyceae	Chaetocerotaceae	*Chaetoceros* sp.
			Chaetoceros socialis
			Cocinodiscus sp.
		Skeletonemaceae	*Skeletonema* sp.
		Melosiraceae	*Melosira* sp.
	Bacillariophyceae	Diploneidaceae	*Diploneis* sp.
			Eucampia sp.
		Pleurosigmataceae	*Gyrosigma* sp.
		Leptocylindraceae	*Leptocylindrus* sp.
		Naviculaceae	*Navicula* sp.
		Bacillariaceae	*Nitzschia* sp.
			Pseudo-nitzschia sp.
		Eupodiscaceae	*Odontella* sp.
	Fragilariophyceae	Licmophoraceae	*Licmophora*
		Thalassionemataceae	*Thalassionema* sp.
Phaeophyta (Brown Algae)	Fucaceae	Common Rockweed	*Fucus vesiculosis*
		Spiral Rockweed	*Fucus spiralis*
		Knotted Wrack	*Ascophyllum nodosum*
	Laminariaceae	Common Kelp	*Laminaria agardhii*
		Finger Kelp	*Laminaria digitata*
		Sea Colander Kelp	*Agarum cribrosum*
Chlorophyta (Green Algae)	Ulvaceae	Sea Lettuce	*Ulva lactuca*
		Green Hair Weed	*Chaetomorpha linum*
		Hollow Green Algae	*Enteromorpha intestinalis*
Rhodophyta (Red Algae)	Gigartinaceae	Irish Moss	*Chondrus crispus*
	Rhodomelaceae	Tubed Weed	*Polysiphonia lanosa*
		Encrusting Red Algae	*Lithothamnium* sp.
	Corallinaceae	Coral Weed	*Corallina officinalis*
	Ceramiaceae	Banded Weed	*Ceramium rubrum*
	Bangiaceae	Purple Laver	*Porphyra umbilicalis*

Chapter 10

Reptiles and Amphibians

Robert Baldwin, Lori Johnson, Daniel Zeh, Timothy Dexter and Leslie Latt

There are thirty-eight species of reptiles and amphibians in Maine. By far the greatest diversity occurs in the southern third of the State, where several species reach their northeasternmost range limits (Hunter *et al*. 1999). Contributing to this reptile and amphibian diversity, southern coastal Maine has a diversity of plant communities and prevalence of wetlands favored by pool-breeding amphibians, some snakes, and rare turtles. Of particular importance are vernal pools—small, isolated wetlands generally unprotected by federal law—that reach high densities in southern Maine and provide habitat for a variety of reptiles and amphibians. These include the state endangered Blanding's turtle and threatened spotted turtle and many more common yet vulnerable reptile and amphibian species. At the same time, southern Maine is experiencing drastic development pressures. Because of the location of Wells NERR in southern coastal Maine, it represents a regionally important opportunity for conservation of reptiles and amphibian habitat. Wells NERR is itself an island in the midst of a rapidly developing coastline. Its diversity of wetland and upland habitats protects populations of reptiles and amphibians. As such, Wells NERR represents a valuable conservation opportunity in the struggle to maintain reptile and amphibian populations in the face of rapidly expanding human settlement. The purpose of this chapter is to review the biology of reptiles and amphibians of southern Maine with special emphasis on those known or suspected to occur in the Reserve, and the potential roles that Wells NERR may play in maintaining these populations.

The Southern Maine Landscape as Reptile and Amphibian Habitat

The current landscape of southern Maine is shaped by climate, geology, land use history and fire. Climatically, southern Maine is the most conducive part of the State for many exothermic vertebrates (reptiles and amphibians) due to latitude and moderating influence of the coast. Geologically, southern Maine was glaciated and this legacy has greatly influenced

the abundance and distribution of wetlands and in particular vernal pools. Isolated ice block depressions west of the inland marine limit tend to be deep, with long and yet seasonal hydroperiods and are consequently high quality vernal pools (Baldwin *et al*. 2006a). Closer to the coast—including the Wells area—clusters of vernal pools formed over glacial marine clays provide multiple breeding habitats of varying hydroperiods important for maintaining a diversity of amphibians (Snodgrass *et al*. 2000).

Land use history has played an extremely important role in structuring reptile and amphibian habitats in southern Maine, as it has throughout New England (Foster *et al*. 2002). Farm abandonment during the last 50 years has resulted in general reforestation (Plantinga *et al*. 1999), and yet, as at Wells NERR, a patchy habitat of open fields, old fields, forests and wetlands remains. Several reptile species favor brushy or open habitats: the Eastern black racer (Maine endangered) is most frequently found in openings in the forested landscape (McCollough *et al*. 2003). As the land reverts to a forested state, many former farm ponds and borrow pits become functional wetland habitats. Spotted salamanders and wood frogs do not discriminate between vernal pools anthropogenic in origin and natural ones, provided the aquatic and surrounding forest environments have naturalized (Baldwin *et al*. 2006b).

At the same time as forests have recovered, pressure for housing development has resulted in sprawl: low density residential development combined with unrestricted road growth (Baldwin *et al*. in press-b). Residential growth rates in southern Maine towns were as high as 30% in the 1990's, indicating a trend towards continued growth and conversion of reforested lands to human uses.

These land use changes are particularly devastating for reptiles and amphibians. Many reptiles and amphibians are especially vulnerable to roads. Roads are attractive for exothermic vertebrates because they are heat islands. Snakes in particular are often killed while basking (Trombulak and Frissell 2000). Other reptiles and amphibians are at risk when they must cross roads during seasonal migrations. Turtles and amphibians, migratory yet slow moving, are at the greatest risk when they must move from one seasonal habitat (e.g., a vernal pool) to another (e.g., a forested wetland) (Forman and Deblinger 2000; Steen and Gibbs 2004).

Maine, like the rest of New England, has experienced rapid growth of the residential road network. Southern Maine in particular has experienced rapid unplanned growth of subdivision-type roads (cul de sacs and circles). The typical road building process is governed at the local government scale. The cumulative impact of building so many small roads can be devastating. In Maine alone over the past two decades nearly 2,000 km of such roads

Family	Common Name	Scientific Name
Ambystomatidae (Mole Salamanders)	Blue SpottedXJefferson Salamander	*Ambystoma lateraleXjeffersonianum*
	Spotted Salamander	*Ambystoma maculatum*
Salamandridae (Newts)	Red Spotted Newt	*Notophthalmus viridescens*
Plethodontidae (Lungless Salamanders)	Redback Salamander	*Plethodon cinereus*
Bufonidae (Toads)	American Toad	*Bufo americanus*
Hylidae (Hylid Frogs)	Spring Peeper	*Hyla crucifer*
	Grey Tree Frog	*Hyla versicolor*
Ranidae (True Frogs)	Wood Frog	*Rana sylvatica*
	Green Frog	*Rana clamitans*
	Bull Frog	*Rana catesbeiana*
Emydidae (Terrapins or Pond Turtles)	Painted Turtle	*Chrysemys picta*
	Blanding's Turtle	*Emydoidea blandingii*
Chelydridae (Snapping Turtles)	Snapping Turtle	*Chelydra serpentina*
Colubridae (Typical Snakes)	Eastern Milk Snake	*Lampropeltis triangulum*
	Eastern Smooth Green Snake	*Liochlorophis vernalis*
	Northern Red-bellied Snake	*Storeria occipitomaculata*
	Eastern Garter Snake	*Thamnophis sirtalis sirtalis*

Table 10-1: Wells NERR Reptiles and Amphibians. Sightings and highly probable habitat for common species.

were built (Baldwin *et al.* in press-b). Not only do the subdivision roads themselves threaten reptiles and amphibians, but the increased traffic onto existing roadways (e.g., primary and secondary highways) poses a major threat.

Another factor structuring the landscapes of southern Maine for reptiles and amphibians is the fire of 1947. This fire burned 15 townships but bypassed the Wells Reserve (Butler 1987). Nonetheless, the forest context for Wells is strongly influenced by this severe crown fire that may have rendered some areas less suitable for some amphibians (Baldwin *et al.* 2006b). Mole salamanders in particular seem to thrive in areas rich in advanced stage decayed wood and mature forests. They appear to be in lower densities in areas burned by the 1947 fire (Baldwin 2005). As a result of this recent fire, the habitat heterogeneity of southern Maine is great; Wells NERR as an unburned portion of the landscape in close proximity to burned townships may be important to study as a refugium for some amphibians.

Southern Maine is at a crossroads for reptiles and amphibians, and Wells NERR is poised to play a pivotal role in restoring and protecting these rare species. Suitable habitat left behind by farm abandonment and reforestation, a plethora of wetlands of many kinds and a high degree of state-level endemism has made southern Maine a focal area of conservation planning for these species. However, rapid rates of land use change and inadequate local control over growth and development threaten landscape integrity for reptiles and amphibians. As it has in the past, Wells NERR can reach beyond its borders to protect the watersheds and landscape context for its ecosystem processes and biodiversity.

Vernal Pool Habitat

Vernal pools are common in the forested landscapes of southern Maine. They are small freshwater wetlands occurring in upland, typically forested settings. Closer to the coast, they are densely clustered while inland they tend to be more isolated, and larger (Baldwin 2005). They are used throughout the year by a variety of reptiles and amphibians for breeding, refuging (finding cover), and foraging. Vernal pools are "isolated wetlands" that are generally isolated hydrologically from the groundwater but, most importantly for understanding their ecology, they periodically dry out. Vernal pools in southern Maine are thus a class of *ephemeral* wetlands, the class of wetlands that receives the least legal protection. Several species of amphibian breeding in vernal pools in New England rely on the pools drying out at least once every 3-5 years (Colburn 2004). This cycle of inundation and drying out insures that fish and other predators of larval amphibians (e.g., bullfrogs and green frogs) cannot become established.

A mass of spotted salamander eggs in a vernal pool. Photo Michele Dionne.

Importantly, reptiles and amphibians using vernal pools are concurrently dependent on habitat in the surrounding forested landscape. Blanding's and Spotted Turtles travel great distances migrating among over-wintering wetlands, breeding sites, and foraging and basking areas in vernal pools (Joyal *et al.* 2001). Garter and ribbon snakes live in the upland forests around vernal pools and forage in vernal pools for larval and adult amphibians (Baldwin *et al.* in press-b). Pool-breeding amphibians have an aquatic larval phase largely dependent upon aquatic conditions (see photos of egg masses and adult spotted salamander), and a terrestrial adult phase dependent largely on forest conditions. As juveniles and adults, their dispersal and migration patterns can carry them across many acres of wetland and upland habitat (Semlitsch 2000).

In southern Maine, no species more completely illustrates the need for habitat connectivity among wetlands and uplands than the wood frog. This species migrates hundreds of meters among spring breeding pools, summer

Common Name	Scientific Name	Status	MBLR	Webhannet	Ogunquit
Eastern Black Racer	*Coluber constrictor*	SE	x		x
Ribbon Snake	*Thamnophis sauritus septentrionalis*	SC	x	x	x
Wood Turtle	*Glyptemys insculpta*	SC	x		
Spotted Turtle	*Clemmys guttata*	ST	x	x	x
Blanding's Turtle	*Emydoidea blandingii*	SE	x	x	x

Table 10-2: Sightings of rare reptiles and amphibians in Wells NERR watersheds. MBLR = Merriland River, Branch Brook, Little River. Status: SE = State Endangered, ST = State Threatened; SC = Special Concern. Source: Maine Department of Inland Fisheries and Wildlife.

forested wetland foraging areas, and upland hibernacula (Baldwin *et al*. 2006a). These linkages among aquatic, wetland and terrestrial environments illustrate the complexity of reptile and amphibian habitat conservation in rapidly developing southern Maine.

Maintaining Habitat in a Rapidly Developing Region

The dynamic nature of the southern Maine landscape is written at the Wells Reserve, where fields and forests in various stages of succession intermingle with freshwater wetlands. These heterogeneous conditions are ideal for maintaining an array of reptiles and amphibian species. In fact, the 1,600 acres at Wells NERR may play an important role in maintaining source populations for the Wells area. Wells NERR records indicate that 18 species have occurred within the reserve boundaries (Table 10-1). Maine Department of Inland Fisheries and Wildlife (MDIFW) records indicate that 5 rare reptile species have been found within the three main watersheds of Wells NERR (Merriland River, Branch Brook and Little River (MBLRO, Webhannet River, and Ogunquit River), only one of which (Blanding's Turtle) has so far been confirmed at the Reserve itself (Table 10-2).

Likewise, there are 17 mapped vernal pools within Wells NERR (Figure 18-1). Surveys of the breeding assemblages and habitat conditions of these pools were conducted in 1996 (Jamie Haskins, MDIFW unpublished data). In 2006, we surveyed the habitat conditions around these pools and conducted GIS analyses of landscape conditions (Table 10-3).

The vernal pools on the Wells Reserve are embedded in a typical New England landscape dominated by regenerating forest and old field. The pools range in depth from 10 to 60 cm. Three quarters of the pools are known to be amphibian breeding sites and three (numbered 2,4 and 7) may be significant breeding sites for wood frogs (Table 10-3). Seven are used by both primary indicator species: wood frogs and spotted salamanders. Most of the pools occur in an undeveloped context, meaning there is appreciable upland or non-breeding habitat quality around them even though some development is certainly present (Table 10-3; Figure 10-1).

Because pond turtles and pool-breeding amphibians migrate among breeding wetlands and non-breeding habitat crossing upland landscapes (Joyal *et al*. 2001), and because pool-breeding amphibian populations (individual pools) are loosely joined by juvenile dispersal (many pools constitute a "metapopulation") (Marsh & Trenham 2001) the pools at Wells NERR occur in a landscape context amenable to long term viability of reptile and amphibian populations. We might be able to say, with further research, that Wells NERR constitutes a functional vernal pool "landscape," increasingly rare in southern Maine.

Wells NERR has 18 confirmed species of reptile and amphibian and it is entirely possible that with more surveys Wells NERR will reveal populations of the additional species found in surrounding watersheds. Thus, Wells NERR represents not only an excellent conservation opportunity for reptiles and amphibians—an island in a sea of coastal rim development—it also represents an opportunity for long term research important for understanding population processes of wetland assemblages of reptiles and amphibians. In this sense, Wells NERR can be viewed as a "reference site" for understanding population processes in a developing landscape. As surrounding habitats become more fragmented from road building Wells NERR populations may be monitored to serve as a benchmark for assessing reptile and amphibian declines. The information gleaned from this kind of research is

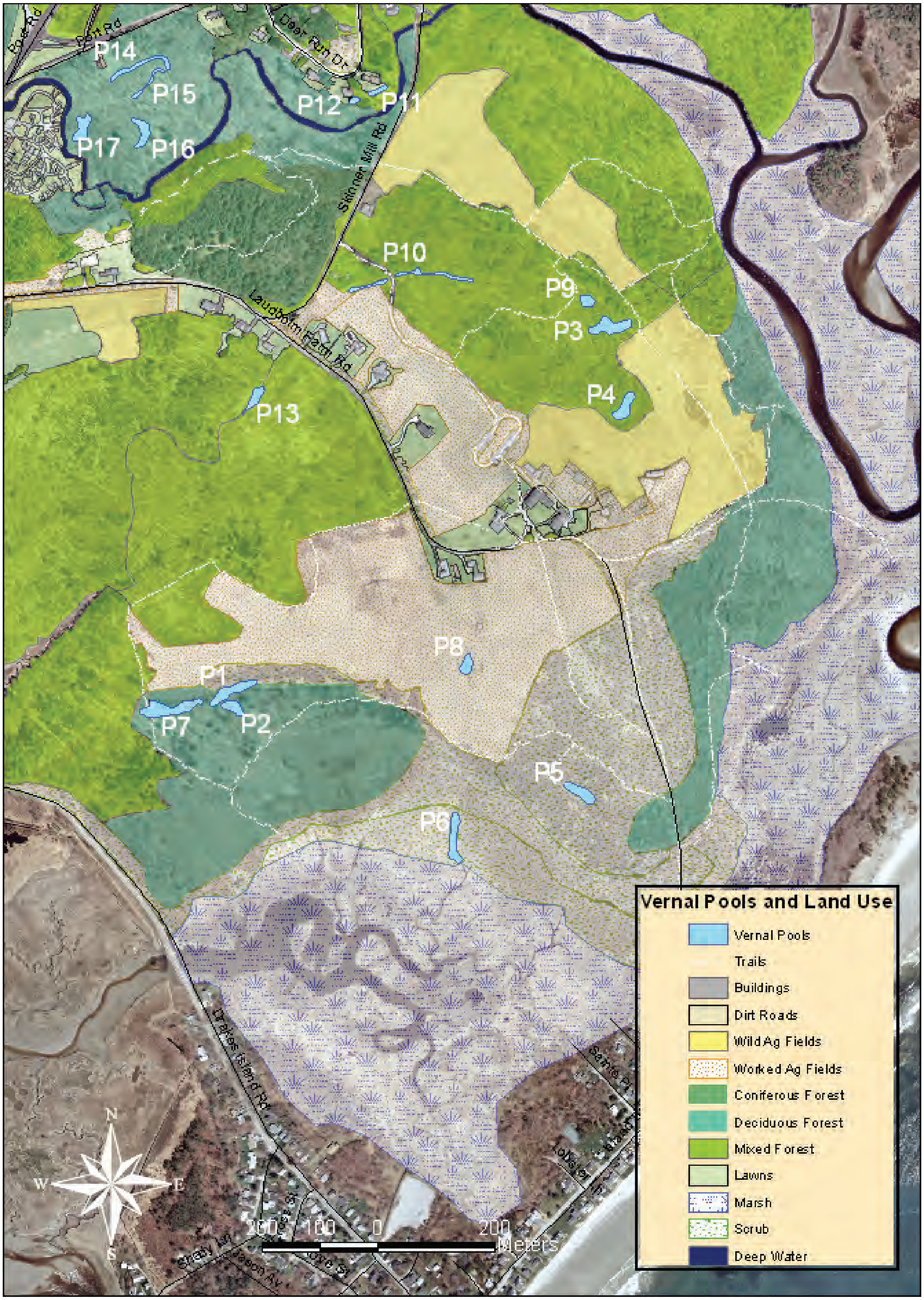

Figure 10-1: Vernal pool habitat and land use at Wells NERR. Map Dan Zeh.

critical for design of conservation plans and for improving regulatory protections (Calhoun *et al.* 2003).

Vernal pools on protected lands such as Wells NERR are rare in southern Maine. Of 542 vernal pools assessed in a southern Maine gap analysis, only 2% occurred on protected lands (Baldwin 2005). Only half of southern Maine pools are protected by any means (wetland, wildlife and shoreland regulations; tree farms and other conservation easements). Half of the pools in southern Maine occur on private lands. Consequently, Wells NERR's conservation efforts at the watershed scale may be essential for protecting some of Maine's most threatened species. Strategies for protection need to include working with landowners through education and purchasing of additional easements, activities in which Wells NERR has long been engaged at the watershed scale.

As with so many reserves across the nation, Wells NERR is becoming increasingly isolated by development. As with other reserves, managers must think beyond reserve boundaries to achieve within-reserve conservation goals. Perhaps the biggest regional impact on reptile and amphibian conservation would be felt through expanding the existing Wells NERR watershed level conservation activities. In particular, identifying and mapping critical habitats (e.g., vernal pools and Eastern black racer habitat), educating landowners, and working with land trusts to purchase easements in the three main Wells NERR watersheds would provide a region-scale service.

Species Accounts

The species accounts below were compiled from a variety of sources; most importantly Carpenter (1952), Ernst *et al.* (1994), Hunter *et al.* (1999), Petranka (1998) and McCollough *et al.* (2003). For engaging treatment of all Maine reptiles and amphibians, see Hunter *et al.* (1999).

Spotted Salamander (Ambystoma maculatum)

A southern Maine vernal pool indicator species, the spotted salamander also breeds in fishless ponds and oxbows of rivers. A large "mole" salamander, it can achieve 8 inches in length. Combined with its striking yellow-on-indigo coloration, it often surprises people with its dramatic beauty. Spotted salamanders, like all pool-breeding amphibians, have a strongly biphasic life

A spotted salamander (Ambystoma maculatum). These elusive amphibians can be seen crossing roads on rainy spring nights, searching for vernal pools where they can mate and deposit egg masses. Photo James Dochtermann.

history. Breeding occurs in pools where larval population dynamics are wholly controlled by aquatic parameters. Upon emergence, juveniles move into surrounding forests where they will live until sexual maturity. Adults live primarily underground, in more mature upland forests, where burrows (made by other animals) and root channels provide shelter and access to food. Slow moving during migration, Spotted salamanders are greatly at risk from southern Maine development.

Blue-Spotted X Jefferson Salamander (Ambystoma lateraleX A. jeffersonianum)

There is biological strangeness afoot in southern Maine forested wetlands. Two species common throughout New England—the Jefferson and Blue-spotted salamander—also hybridize and produce offspring that contain three or four sets of chromosomes (polyploidy). It is likely that in southern Maine, what is encountered most is the hybrid. These species have a similar life history to closely related spotted salamanders: they breed primarily in vernal pools and migrate to and from surrounding forested habitat. Also slow moving, they are at risk from automobiles.

Eastern Newt (Red-spotted Newt) (Notophthalmus viridescens)

Eastern newts are found in aquatic and terrestrial habitats throughout southern Maine. The Eastern newt is quite different from most other salamanders in North America because of its complete reliance on aquatic habitats as adults and contrasting complete reliance on

A red eft (right) and a red spotted newt (left), placed on a log for viewing. The red eft is the juvenile terrestrial form of (Notopthalmus viridescens) and develops into the adult aquatic form. Photo Wells NERR.

terrestrial habitat as juveniles. Larvae generally develop into the "red eft" terrestrial stage (at right in photograph above) during their first year, mostly inhabiting woodlands. They remain at this stage for 2-7 years. During this period they are usually bright orange with small, red dorsal spots, and have dry skin. Following this stage, they return to water and transform into breeding adults that are olive green, have small black as well as red spots, flattened tails, and slimy skin. Although the destruction of woodlands has resulted in the loss of some populations, this species remains abundant because of its ability to colonize many different types of aquatic habitats including anthropogenic water bodies.

Northern Redback Salamander (Plethodon cinereus)

Northern redback salamanders are very common, but they are not easily found unless you look under leaf litter or woody debris, or even inside very rotten wood during the driest and coldest parts of the year. This species has 3 different types that differ in coloration: red-back, lead-back, and erythristic. The red-back variety (most common) has dark sides and a wide, colored stripe running down the back that can be red, green, brown or yellow. Redbacks spend their entire life cycle on land. Eggs are laid under rocks or within rotting logs and are attended by adults. In southern Maine, redbacks are often found living in or near the giant pine stumps left behind by mid century logging. Because of their abundance and their role as predators of the tiny invertebrates that break down organic matter, redbacks are important for the whole ecosystem. Studies in New England forests have shown that because of sheer numbers and foraging activities redbacks may actually play a role in regulating greenhouse gasses, because they eat the organisms primarily responsible for releasing carbon dioxide from the forest floor.

American Toad (Bufo americanus)

The toad is one of the most common amphibians in southern Maine, although is also threatened by roads and habitat destruction. American toads (pictured below) have dry, warty-looking skin with large, prominent glands behind each eye containing a noxious substance that deters many would-be predators. Toad vocalizations are a sustained, dry trill. Toads breed in open shallow water. Juveniles and adults disperse into fields, forests, wetlands, yards, and are often found around gardens in highly developed areas. Their ability to use this wide variety of habitats no doubt contributes to their widespread distribution, but also their susceptibility to roads.

American toad (Bufo americanus). Photo Sue Bickford.

Gray Tree Frog (Hyla versicolor)

As its name implies, the gray treefrog is found in trees or shrubs rather than on the ground or in water. Gray tree frogs have green, brown and off-white colors that blend in with their backgrounds, making it extremely difficult to find them on bark. Large toe pads allow them to adhere to vertical surfaces from which they call. Gray tree frog vocalizations are a repetitive, short, high-pitched trill with each one lasting less than half a second. They exist throughout the year in forested areas near ponds and wetlands including vernal pools.

Spring Peeper (Pseudacris crucifer)

Spring peepers are the smallest frog in Maine and are rarely seen, but often heard singing from their shrubby breeding wetlands – including many vernal pools. They have a very loud, high-pitched breeding vocalization (the "peep"). Despite their cacophony, they are nearly impossible to spot. Look on the stems of cattails and shrubs emerging from the wetland. Peepers are tiny (max. length 1.5 in.) and become silent at the slightest disturbance to their wetlands. They are a pale golden-brown, with a noticeable cross pattern on the back. Research has shown that this species is negatively affected by the acidification of wetlands due to acid rain, because developing larvae have a harder time functioning in a lower pH.

Bullfrog (Rana catesbeiana)

Bullfrogs are the largest frogs in southern Maine, reaching up to 8" in length. They are green to brown and may be lightly mottled with darker colors, with smooth, not ridged, backs. Bullfrogs are voracious predators making them a problem species in regions of the United States where they have become invasive and eat native frogs in addition to just about any other animal they can fit into their capacious maws. They are aquatic frogs with a multiple-year tadpole stage, requiring lakes, slow-moving rivers, and permanent ponds for breeding. Like other frogs, they migrate among wetlands to forage and breed.

Green Frog (Rana clamitans)

The green frog is a very common species throughout southern Maine and can inhabit almost any type of wetland. Like bullfrogs, green frogs require aquatic habitats for breeding but also migrate among a variety of wetland types. In southern Maine they are frequently found foraging in vernal pools, especially after tadpoles have hatched, and they also eat large amounts of larval macroinvertebrates. In contrast to the bullfrog, green frogs have prominent ridges that run down the back starting at each eye. Their breeding vocalization sounds like a banjo string being plucked and they are often the first to report the presence of an intruder in their habitat, releasing a loud chirp and jumping in the water for safety. Juvenile green frogs migrate away from breeding ponds to moist forested wetlands to spend dry summer months where their habitat use overlaps with those of the wood frog.

Green frog (Rana clamitans) in duckweed. Photo Ward Feurt.

Wood frog (Rana sylvatica). Photo Robert Baldwin.

Wood Frog (Rana sylvatica)

The quintessential vernal pool frog, the wood frog emerges from hibernation in upper soil horizons of upland forests in the very early spring and travels overland to its breeding pools. Males congregate in vernal pools and make their famous "quacking" calls. Females join later and massive rafts of egg masses are formed (hundreds in particularly good vernal pools). After breeding, the adult wood frog travels as far as hundreds of meters to neighboring forested swamps where it spends the dry summer months. Wood frogs retain moisture during the summer by burying themselves in piles of moist leaves or sphagnum moss. Juveniles leave breeding pools by mid summer and disperse into surrounding woodlands. Because of the importance of surrounding forests for wood frogs, their movements place their populations at great risk from new road building.

Blanding's turtle (Emydoidea blandingii). Photo Sue Bickford.

Blanding's Turtle (Emydoidea blandingii)

Blanding's turtles have an unusual range. They are most numerous in the Midwest United States and then not found between the Midwest and eastern New York. Farther east still, there are isolated groups of populations in New Hampshire, Massachusetts, southern Maine, and Nova Scotia. Their scattered distribution makes them a high-priority rare species in many states. Because of their size, brightly-speckled or streaked carapace, and yellow chin and throat, they would be quite noticeable if not for the fact that they spend most of their time submerged in wetlands. They prefer shallow wetlands with dense aquatic vegetation such as ponds (including larger vernal pools), marshes and small streams. Blanding's turtles migrate great distances between their upland nesting and wetland hibernating habitats, so roads that pass through their migration routes pose a serious threat to this species. Sightings in southern Maine should be reported to the Maine Department of Inland Fisheries and Wildlife (MDIFW).

Spotted Turtle (Clemmys guttata)

When viewed swimming through a tannin-rich vernal pool, all one can see of a spotted turtle is a constellation of yellow spots (see photo on first page of chapter). When held to the light, their full beauty comes out. Spotted turtles are blackish green with small, yellow spots on the carapace, head, neck and legs, and are small. They have a maximum carapace length of about 6 inches. They prefer shallow wetlands such as marshes, swamps and vernal pools—wetland habitats among which they migrate great distances. Spotted turtles are listed as rare in many states, including Maine, because of habitat loss and degradation. In southern Maine, numerous spotted turtles are killed while migrating across roads. Common predators such as raccoons and skunks also impact populations, as do illegal collections. Any sightings in southern Maine should be reported to MDIFW.

Painted Turtles (Chrysemys picta)

Painted turtles are the species we see all the time in and around ponds, lakes and slow-moving rivers. They are highly colorful with an attractive, smooth olive-green carapace that has red markings on the outer edges and scutes and red and yellow stripes on the head. Painted turtles are very common, doing well in a variety of aquatic habitats such as ponds, marshes, and shallow, slow-moving streams. As with snapping turtles, they are also known to live in brackish waters. They are often seen basking on top of logs or floating debris. Similar to all other turtle species in southern Maine, painted turtles need to migrate to sand or open dirt to nest. Therefore, populations can be negatively impacted by roads and increases in local nest predators such as raccoons and skunks.

Wood Turtle (Glyptemys insculpta)

Wood turtles have a brownish-gray carapace with a maximum length of 9.5 inches and bright orange skin on the legs and neck. New scutes on their carapaces can "build up" over time giving them a pyramidal appearance. This species is associated with riparian habitats where they typically spend the winter, spring and fall. In the summer, they move into other nearby wetland habitats such as oxbows and wet meadows and occasionally fields and pastures. Roads and habitat loss threaten wood turtle populations. Recent research done in Massachusetts also shows that individual wood turtles inhabiting riverine systems adjacent to agricultural lands have been destroyed by farm equipment when present at the edge of pasture and fallow fields.

Common Snapping Turtle (Chelydra serpentina)

A fearsome species of turtle if you grew up around ponds and lakes in southern Maine where the mythology was that the snapper would take toes off. The reality is the snapping turtle (see photo) rarely hurts anyone and is in fact declining. In many states such as Maine, snapping turtles are still harvested for their meat. As for other tur-

A snapping turtle (Chelydra serpentina). Photo Ward Feurt.

tles, many are killed while crossing roads. Compounding their difficulties, females often nest on warm, sandy roadsides exposing hatching juveniles to road mortality. When not migrating, snapping turtles spend most of their time in muddy lakes, ponds and slow-moving rivers. They are also known to use brackish estuaries.

Milk snake (Lampropeltis triangulum). Photo Sue Bickford.

Eastern Milk Snake (Lampropeltis triangulum)

The Eastern milk snake (see photo) is handsomely patterned with three to five dorsal rows of brown or reddish blotches on a tan or gray background. When threatened it appears to mimic a timber rattlesnake by rattling its tail in dry leaves. It prefers mixed brush and meadows along woodlands. The milk snake hunts at night. It often lives near human habitation and is beneficial in controlling rodent populations. It also eats amphibians, small birds, insects, eggs and other snakes. The milk snake reaches the northeastern limit of its range in central Maine. It may be declining in southern Maine as old fields revert to forests and as roads fragment its habitat.

Smooth Green Snake (Liochlorophis vernalis)

The vivid green dorsum of the smooth green snake offers near complete camouflage in the grassy open habitats it prefers. The smooth green snake hunts during the day for insects, spiders and small vertebrates. Although it occurs most frequently in the settled portions of the State where historically there were abundant fields, numbers may be declining in southern Maine as farms revert to forest. The open areas of Wells NERR may provide particularly good habitat for the smooth green snake.

Eastern Garter Snake (Thamnophis sirtalis sirtalis)

The Eastern garter snake is the most widespread and abundant reptile in southern Maine. Its typical coloration includes three thin yellow or brown dorsal stripes. It is easily confused with the ribbon snake which has a longer tail and crisper stripes. The garter snake is the earliest snake to emerge from hibernation in spring. Garter snakes are important to southern Maine aquatic and terrestrial food webs. Vernal pools are favored habitats, where they eat adult and larval amphibians. Garter snakes are themselves an important food source for hawks, skunks, foxes and other snakes.

Eastern Ribbon Snake (Thamnophis sauritus)

The Eastern ribbon snake is a slender snake boldly marked with three bright yellow or buff stripes against a dark background. Its long slim tail, one third the length of its body, distinguishes it from the garter snake. The ribbon snake is semi-aquatic. Amphibians, especially metamorphosing tadpoles, make up the bulk of its diet, supplemented by insects, spiders and fish. It reaches the northeastern limit of its range in central Maine. However, its favored habitat, outwash plain pond shores, occurs mostly in York and Cumberland Counties. It is especially threatened by the loss and degradation of wetlands, including vernal pools and their surrounding uplands, which provide its main food source.

Eastern Black Racer (Coluber constrictor)

The Eastern black racer (pictured at end of chapter) is a long, slender, black snake named for its speed. Juveniles, heavily blotched at birth, lose their patterning as they grow. Racers hunt diurnally for invertebrates and other small vertebrate animals. This is a circumstance where

Vernal Pool #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Totals
Depth (m)	0.3	0.6	0.3	0.3	0.3	0.1	0.6	0.2	0.2	0.5	0.3	0.5	0.1	0.3	0.4	0.4	0.4	.34 ave. depth (m)
Presence Aquatic Macrophytes (Y/N)	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y = 5, N = 12
Estimated number of egg masses for amphibian indicator species																		Total estimated number of egg masses
Wood Frog	20	40	5	150	20		50		2	1	10		7	10				315
Spotted Salamander			15	25					1	2	4	3	8	11		8		77
Relative frequencies (%) of upper canopy trees in surrounding habitat																		Total relative frequency (%) of upper canopy trees for all vernal pools
Balsam Fir													3.0%					0.2%
Black Birch			3.9%	18.4%	10.0%									8.6%	10.7%	10.7%	3.9%	4.1%
Paper Birch			26.9%	12.2%	20.0%	15.2%			2.6%	3.8%	18.2%	11.1%	12.1%	28.6%	6.7%	17.9%	26.9%	12.6%
Red Maple	69.2%	63.2%	26.9%	30.6%	70.0%	84.9%	46.7%		12.8%	13.2%	27.3%	11.1%	42.4%	22.9%	31.1%	14.3%	26.9%	37.1%
Red Oak	23.1%	21.1%	25.0%	20.4%			26.7%		61.5%	15.1%	27.3%	66.7%	27.3%	40.0%	51.1%	57.1%	25.0%	30.5%
Red Spruce				18.4%					10.3%	30.2%								3.7%
Sugar Maple													6.1%					0.4%
White Pine	7.7%	15.8%	17.3%				26.7%		12.8%	17.0%	27.3%	11.1%	9.1%				17.3%	10.1%
Yellow Birch										20.8%								1.3%
Immediate surrounding habitat containing hayfield or landscaped land (Y/N)	Y	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	Y = 5, N = 12
Land use/cover (%) cover within 200m of vernal pools																		Total land use (%) coverage within 200m buffers for all vernal pools
Lawns				1.1%				3.8%		4.8%	3.7%	3.6%	7.9%	14.7%	11.7%	9.9%	15.7%	4.6%
Roads and Surfaces			0.2%	2.0%				0.6%		3.9%	5.4%	5.5%	3.4%	8.6%	5.7%	4.2%	9.0%	2.9%
Dirt Roads				0.7%				0.3%						1.7%	1.5%	0.5%	0.6%	0.3%
Buildings				1.9%				0.7%		1.0%	2.0%	2.1%	1.1%	2.0%	1.4%	1.1%	2.2%	0.9%
Inactive Farmland	25.5%	22.2%	0.5%	12.3%	7.4%	7.6%	14.5%	63.4%					4.7%					9.0%
Active Farmland			33.0%	45.4%					26.4%	10.8%	19.8%	16.3%						8.8%
Mixed Forest	27.2%	20.1%	63.4%	33.4%			47.0%		73.6%	12.1%	31.9%	26.2%	76.8%	11.9%	13.8%	14.0%	16.9%	27.1%
Conifer Forest										52.5%	8.3%	11.7%	5.0%	4.5%	4.4%	9.7%	0.9%	6.7%
Deciduous Forest	41.9%	51.9%	2.7%	3.3%	8.2%	8.8%	33.9%	7.3%		13.9%	22.8%	28.3%		49.6%	54.5%	53.9%	47.6%	25.2%
Marsh			0.3%		0.5%	35.3%												2.2%
Shrubs	5.5%	5.8%			83.9%	48.3%	4.6%	23.9%		0.2%	2.4%	2.5%	1.1%	1.9%	1.4%	1.7%	2.5%	10.8%
Deep Water (barrier)										0.7%	3.7%	3.7%		5.1%	5.6%	5.0%	4.6%	1.6%

Table 10-3: Characteristics of vernal pools at Wells NERR. Amphibian breeding data collected April 1997 by Jamie Haskins (MEDIFW), habitat data collected November 2006 by T. Dexter, and land use data remotely collected and analyzed Fall 2006 by D. Zeh.

the scientific name is not descriptive: they kill by bite rather than constriction. If pursued, a racer will often flee upward into shrubs or branches, and will fight fiercely if cornered. The only substantial population occurs in dry brushy habitat in Wells and Kennebunk, although sightings have been reported from other towns in York and Oxford Counties. Because of its territoriality and limited range the black racer is particularly vulnerable to sprawl and habitat degradation.

Northern Red-bellied Snake (Storeria occipitomaculata)

The Northern red-bellied snake is a small secretive reptile with variable coloration most often with a red belly, brown or slate gray dorsum and three tan spots on the nape of the neck. They are habitat generalists, occurring in most southern Maine areas. They can be found hiding beneath rocks, bark and wood. Southern Maine gardeners should encourage this species: slugs make up as much as 90% of its diet. The geographical range of the red-bellied snake includes almost all of Maine.

MDIFW biologist holding a rare Eastern black racer of Southern Maine. Photo Parker Schuerman.

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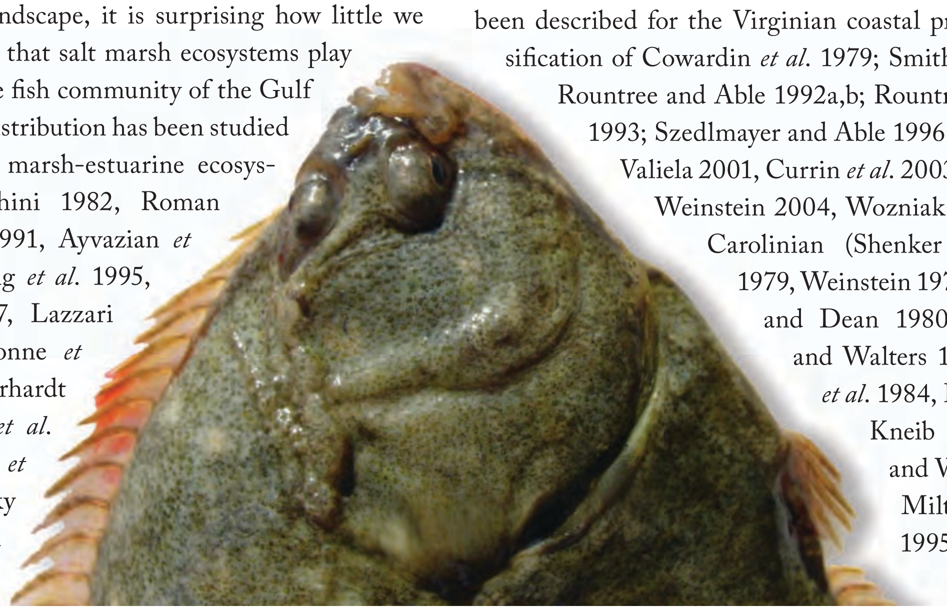
Chapter 11

Fish

Michele Dionne and James Dochtermann

The ecology of fish populations and communities using the marsh-estuarine ecosystems in the Gulf of Maine has been little explored. Many intriguing questions are waiting to be posed and investigated, especially in the numerous estuaries that characterize the Seacoast Region (southcoast Maine and coastal New Hampshire), of which the Reserve's estuaries are representative. Nearly 50% of the salt marsh acreage along the Gulf of Maine coastline is located on the coast of Maine (Jacobson *et al*. 1987), more than twice that of any other Gulf of Maine coastal state, and more than any state north of New Jersey. Given the important place of salt marshes in the coastal landscape, it is surprising how little we know of the role that salt marsh ecosystems play in supporting the fish community of the Gulf of Maine. Fish distribution has been studied in a handful of marsh-estuarine ecosystems (Lamborghini 1982, Roman 1987, Murphy 1991, Ayvazian *et al*. 1992, Doering *et al*. 1995, Cartwright 1997, Lazzari *et al*. 1999, Dionne *et al*. 1999, Eberhardt 2004, Morgan *et al*. 2005a,b, Dionne *et al*. 2006, Konisky *et al*. 2006). Fish diets and food webs have been studied in yet fewer marshes (Lamborghini 1982, Cartwright 1997, Deegan and Garritt 1997). Nursery function for post-larval and juvenile fishes and foraging habitat value for adult marine fish are poorly understood.

There is a substantial body of ecological research that has focused on fish and decapod crustaceans (together referred to as nekton) in more southerly marshes (New Jersey to Georgia; see Day *et al*. 1989, Rozas 1995, Kneib 1997, and Weinstein and Kreeger 2000, for reviews). Nursery and adult foraging functions have been described for the Virginian coastal province (classification of Cowardin *et al*. 1979; Smith *et al*. 1984; Rountree and Able 1992a,b; Rountree and Able 1993; Szedlmayer and Able 1996, Griffin and Valiela 2001, Currin *et al*. 2003, Litvin and Weinstein 2004, Wozniak *et al*. 2006); Carolinian (Shenker and Dean 1979, Weinstein 1979, Bozeman and Dean 1980, Weinstein and Walters 1981, Rogers *et al*. 1984, Hettler 1989, Kneib 1993, Kneib and Wagner 1994, Miltner *et al*. 1995, Irlandi



and Crawford 1997), and Louisianan coasts (Boesch and Turner 1984, Felley 1987, Deegan *et al*. 1990, Deegan 1993, Peterson and Turner 1994, Minello and Webb 1997). The results of this work do not directly apply to the Gulf of Maine, given its dramatically different climate, geology, marsh plant communities, substrates and tides, not to mention species assemblage.

Fifty-seven fish species have been identified within the Reserve's estuaries and adjacent waters of the Wells Embayment (Table 11-1). These species represent three life history patterns that we have simplified from the seven patterns described by Ayvazian *et al*. 1992 (following the classification of McHugh 1967): **resident**, **migratory** (anadromous and catadromous), and **transient**. Estuarine residents are species that spawn and spend a significant part of their life in the estuary. Migratory fish are those with an anadromous or catadromous life history. Here the transient life history habit includes the "spawner" (marine species that spawn in estuaries), "nursery" (marine species that spawn in ocean waters but use the estuary as a nursery), and "marine" (marine fish that visit the estuary as adults) classifications (Table 11-1).

Wells NERR and affiliated scientists have investigated nekton distribution and abundance of both back-barrier and fringing marshes in the region. Early studies focused on basic species surveys in the Webhannet and Little River estuaries, followed by assessments of fish foraging; nekton response to marsh restoration, land use, and oil contamination; and trophic transfer of mercury. In the overview that follows, we present synopses of these projects, as well as relevant studies from other Gulf of Maine marsh-estuarine ecosystems.

Research Overview

A Regional Assessment of Salt Marsh Restoration and Monitoring in the Gulf of Maine (Konisky et al. 2006)

Most salt marsh ecosystems in the Gulf of Maine have been hydrologically fragmented, especially by road crossings with undersized and poorly placed culverts and tide gates (pictured). To evaluate the response of hydrologically altered salt marsh systems to restoration, data were compiled from 36 Gulf of Maine salt marsh restoration and reference sites (Fig. 11-1) monitored voluntarily using a standardized protocol (Neckles and Dionne 2000, Neckles *et al*. 2002). Protocol indicator variables measure aspects of soils, hydrology, vegetation, birds and nekton. While soils were monitored at 78% of paired restoration and reference sites, and vegetation at 89% of sites, nekton variables were measured much less frequently (species richness – 56%, density – 36%, length – 47%, biomass – 36%). In addition, at many sites, sampling methods provided only relative abundance measures of a subset of species. Twenty-four nekton species (18 fish, 3 crabs and 3 shrimp) were identified from the pooled data: 20 species from reference sites, 13 from pre-restoration sites and 13 from restoration sites. Seven of these species were found only at reference sites, and three only at restored sites. Mean species richness was similar among reference (3.5), pre-restoration (3.2) and post-restoration sites (3.0 to 3.6). There were no significant differences in fish density for pre-restoration sites, sites 1 year post-restoration, and sites 2 or more years post-restoration (5 – 6 fish m^{-2}). The fish monitoring protocol was revised in 2005 to simplify the sampling gear and encourage greater protocol implementation (Taylor 2007).

Developing an Index of Tidal Wetland Health in the Gulf of Maine using Fish as Indicators. (Dionne et al. 2006)

Fringing salt marshes are widespread throughout coastal Maine, yet their narrow dimensions have prevented adequate mapping and quantification. In Casco Bay, fringing marsh habitat is increasingly subject to upland runoff and other changes associated with intense shoreland development. A set of 12 fringing marshes were selected in a stratified random design to assess nekton response

Tide gates deprive many acres of former salt marsh from tidal flow. Photo Michele Dionne.

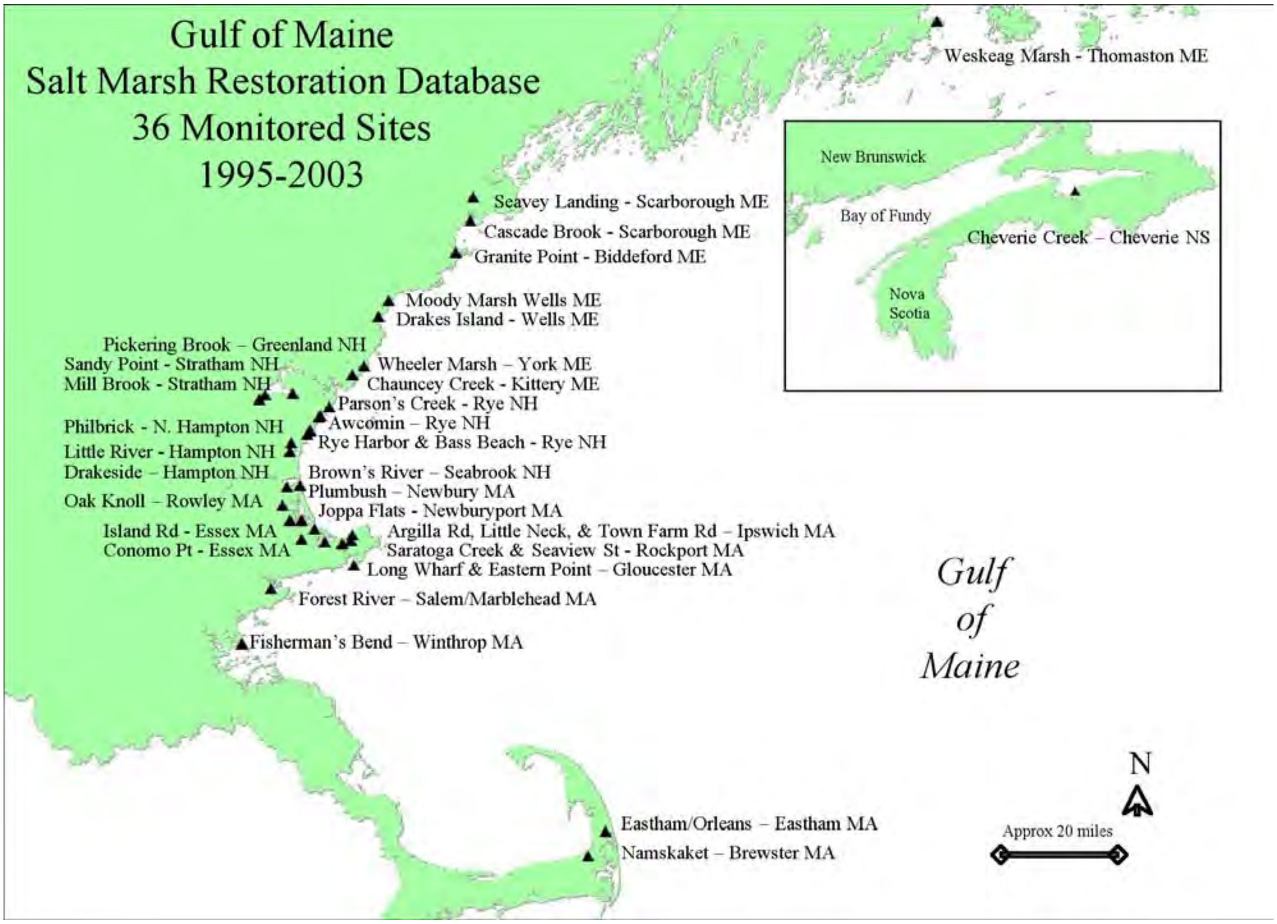


Figure 11-1: Study sites for regional assessment of salt marsh restoration (Konisky *et al*. 2006).

to the effects of adjacent land use, with 4 replicate sites representing low, intermediate and high levels of land use impact. Species identity, density, and biomass were used to develop candidate metrics for a tidal marsh index of biotic integrity. Twenty-two species were identified, and individuals counted and weighed in fyke net samples from marsh segments of known area (see photo of fyke net). Twenty candidate metrics were tested for trends related to impact level. Four metrics showed a positive response to impact: green crab % biomass, *Fundulus* biodensity, *Fundulus* density, tomcod % biomass. Ten metrics revealed a negative trend: shrimp % biomass, tomcod biodensity and density, piscivore biodensity and density, total piscivores, other fish (i.e., non-*Fundulus*) biodensity and density, total other fish, and native species richness. In future work, these metrics will be further tested with additional fish data and related to a more quantitative assessment of land use for the 12 sites.

An Estimate of the Economic Value of Southern Maine Tidal Wetlands to the Maine Commercial Groundfish Industry (Hayes 2005)

Explicit knowledge of the economic value to society of ecosystem services often provides motivation for investment in better management of the ecosystems concerned, to ensure the continued flow of economic benefits. This study estimates the economic value of tidal wetlands in southern Maine (from approximately Damariscotta to the New Hampshire border) to the commercial ground fishing industry of Maine. The dependence of scientific trawl biomass (from the Maine and New Hampshire Inshore Trawl Survey and the NOAA / NMFS / Northeast Fisheries Science Center's Bottom Trawl Survey) on the nearest wetland area was determined using linear regression. This dependence was used to estimate the commercial fisheries' production function dependence on (the marginal product of) those same wetland areas. This was used to obtain an estimate of the economic value of those wetlands to the industry and society. Marginal

Scientific Name	Common Name	Life history	Maine & Seacoast NH [1]	Maine & Seacoast NH [2]	Herring River, MA [3]	Little River, ME [4]	Little River, ME [5]	Wells Harbor, ME [6]	Webhannet River, ME [7]	Kennebec Point, ME [8]	Bass Harbor Marsh, ME [9]	York River, ME [10]	Casco Bay, ME [11]	Montsweag, ME [12]	Piscataqua River, NH [13]	Saco River, ME [14]	Saco River, ME [15]	Kennebec River, ME [16]
Alosa aestivalis	Blueback Herring	m(a)			x	x		x		x				x			x	x
Alosa mediocris	Hickory Shad	m(a)			x												x	
Alosa pseudoharengus	Alewife	m(a)			x	x		x		x		x	x	x			x	x
Alosa sapidissima	American Shad	m(a)	x			x											x	
Brevoortia tyrannus	Atlantic Menhaden	t			x	x					x							
Clupea harengus	Atlantic Herring	t	x			x		x		x	x	x	x	x				
Ammodytes americanus	Sand Lance	t				x				x		x				x		
Anguilla rostrata	American Eel	m(c)	x	x	x	x	x	x			x	x	x	x			x	x
Apeltes quadracus	Fourspine Stickleback	r	x	x	x	x	x	x	x	x	x	x	x	x		x		
Gasterosteus aculeatus	Threespine Stickleback	r	x			x	x	x	x	x	x	x	x	x				
Gasterosteus wheatlandi	Blackspotted Stickleback	r	x			x	x	x	x	x	x			x				
Pungitius pungitius	Ninespine Stickleback	r	x	x		x	x	x	x	x	x	x	x	x				
Cyclopterus lumpus	Lumpfish	t				x				x		x						
Liparis atlanticus	Seasnail	t				x												
Decapturus macarellus	Mackerel Scad	t								x								
Fundulus heteroclitus	Mummichog	r	x	x	x	x	x	x	x	x	x	x	x					
Fundulus majalis	Striped Killifish	r	x	x	x					x								
Gadus morhua	Atlantic Cod	t								x								
Microgadus tomcod	Atlantic Tomcod	t	x			x	x	x		x		x	x	x	x	x		
Pollachius virens	American Pollock	t								x	x	x	x					
Urophycis chuss	Red Hake	t								x		x				x		
Urophycis tenuis	White Hake	t				x		x		x			x	x				
Menidia beryllina	Inland Silverside	r						x										
Menidia menidia	Atlantic Silverside	r	x	x	x	x	x	x	x	x	x	x	x	x	x			
Menidia peninsulae	Tidewater Silverside	r			x													
Morone americana	White Perch	t	x		x					x		x					x	x
Morone saxatilis	Striped Bass	t	x			x				x		x					x	x
Mugil cephalus	Striped Mullet	t				x												
Hemitriperus americanus	Sea Raven	t								x								
Myoxocephalus aeneus	Grubby Sculpin	t				x						x			x			
Myoxocephalus octodecimspinosus	Longhorn Sculpin	t				x				x								
Myoxocephalus scorpius	Shorthorn Sculpin	t								x								
Osmerus mordax	Rainbow Smelt	m(a)				x		x		x		x			x			
Peprilus tricanthus	Butterfish	t				x												
Petromyzon marinus	Sea Lamprey	m(a)				x											x	x
Pomatomus saltatrix	Bluefish	t			x	x				x		x	x					
Pholis gunnellus	Rock Gunnell	r				x										x		
Pleuronectes ferrugineus	Yellowtail Flounder	t									x							
Pleuronectes putnami	Smooth Flounder	t										x	x	x				
Pseudopleuronectes americanus	Winter Flounder	t		x	x	x	x			x		x	x	x	x			
Rajidae sp.	Skate	t													x			
Scopthalmus aquosus	Windowpane	t				x												
Salmo salar	Atlantic Salmon	m(a)				x											x	x
Salmo trutta	Brown Trout	m(a)				x						x						
Salvelinus fontinalis	Brook Trout	m(a)				x					x	x						
Scomber scombrus	Atlantic Mackerel	t			x	x												
Sphyraena borealis	Northern Sennet	t																
Syngnathus fuscus	Northern Pipefish	t			x	x		x		x	x	x		x				
Tautogolabrus adspersus	Cunner	t					x					x		x	x			

r = resident species, t = transient species, m(a) = marine anadromous species, m(c) = marine catadromous species

Table 11-1: Fish species list for Wells NERR and other Maine estuaries. Note that these studies used a variety of fish sampling methods and a range of sampling effort. This list excludes accidentals and strays; see Table 11-2 for a complete list of species found at the Wells NERR.

Table 11-1: References

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values (dollars per square meter) for seven commercial fish species and five wetland types successfully modeled, ranged from zero to $14.31 m^{-2}. A conservative estimate of the total value flowing to society from the wetlands studied through this means was estimated to be over $32 million per year (2003 U.S. dollars).

Ecological Functions and Values of Fringing Salt Marshes Susceptible to Oil Spills in Casco Bay, Maine (Morgan et al. 2005)

Fringing marshes are abundant intertidal habitats along much of Maine's coast. In terms of vegetation, they are similar to the channel edges of much larger back-barrier marshes such as those at Wells NERR, with a sloping low marsh shoulder grading into high marsh. Rather than forming a broad high marsh plain, the fringing marsh hugs the upland edge in a narrow band, typically 10 m to 30 m wide. Because of their narrow width, fringing marshes are greatly under-represented by coastal wetland mapping programs, and consequently have received little attention by scientists or managers. The plant, invertebrate and nekton communities were surveyed at 9 fringing marsh sites in Casco Bay, Maine, in the vicinity of Portland Harbor, Northern New England's largest oil shipping port. The survey established baseline data for use in damage assessment, should fringing marshes be affected in the event of an oil spill. Five marsh resident fish species were present at all sites over two years (2002 – 2003): mummichog, Atlantic silverside, and three stickleback species (threespine, fourspine, ninespine), as well as juvenile smooth flounder, a marine transient. Other marine transients were Atlantic herring, winter flounder, and hake (red / white). Resident biomass density exceeded that of marine transients by fourfold. Migratory species were present at most sites in both years: American eel, alewife, rainbow smelt and tomcod. Mean biomass densities in g m^{-2} for the 2002 – 2003 pooled data was $\bar{x}$ = 0.21 ± 0.061 SE for residents, $\bar{x}$ = 0.05 ± 0.035 SE for transients, and $\bar{x}$ = 0.13 ± 0.045 SE for migratory species. The non-native green crab was present at all sites on all dates, and at much greater biomass than the other macrocrustaceans (rock crab, jonah crab, hermit crab, and sand shrimp). In fact, the green crab biomass density was tenfold higher than that of the resident fishes at $\bar{x}$ = 2.24 ±0.74 SE for the pooled data. In a 2004 follow up study (Morgan *et al*. 2005b) comparing 3 fringing marsh sites that had been contaminated in a 1996 oil spill with three

Fyke net set for fish sampling in a Casco Bay fringing marsh. Photo Michele Dionne.

reference marshes, 10 fish and 2 crustacean species were collected, all of which were present in the 2002 – 2003 survey. Interestingly, American eel, tomcod, and smooth flounder were collected only at reference sites. The sand shrimp also was better represented at the reference than at the impact sites. Green crab biomass density was greater in the reference than in the impact sites (≈ 1.7 vs. ≈ 0.8 g m^{-2}), but fish biomass density in the impacted sites was twice that of the reference sites (≈ 0.4 vs. ≈ 0.2 g m^{-2}). Fish at the impact sites may have experienced an increase in growth due to release from green crab predation risk.

Bioaccumulation of Metals in Intertidal Food Webs (Chen et al. 2004)

Numerous New England estuaries have been contaminated by mercury (Hg), but the potential movement of mercury through estuarine food webs has not been investigated (Fig. 11-2). A pilot study was conducted to characterize Hg bioaccumulation in intertidal food webs in four different Gulf of Maine sites: Great Bay, NH (Adams Point, Portsmouth Naval Shipyard), Webhannet Estuary ME, and Mount Desert Island ME), which differ in physical, chemical, and land use characteristics. For each site, the bioaccumulation and trophic transfer of Hg in the resident and transient benthic, epibenthic, and nektonic species inhabiting the intertidal and subtidal portions of these systems were quantified. Hg bioaccumulation was measured at multiple trophic levels and relative trophic position and food source was estimated using stable isotopes ($\delta^{15}N$ and $\delta^{13}C$). Results of the study show different patterns of Hg bioaccumulation and trophic transfer depending on the site and taxonomic group. All species measured for Hg from the Webhannet estuary contained < 0.02 μg gww^{-1}, while values ranged up to ≈ 0.10 μg gww^{-1} in Great Bay. However, differences in trophic position or food source did not predict Hg bioaccumulation. Results suggest that both benthic and pelagic food webs may be important pathways for Hg trophic transfer in estuarine systems.

Fish Versus Human Corridors: The Impacts of Road Culverts on Nekton Community Composition and Movement in New England Salt Marshes (Eberhardt 2004)

Many Gulf of Maine salt marshes are transected by at least one transportation crossing (e.g. road, railroad, causeway). Marsh channels are often blocked; undersized, poorly placed, culverts provide the only hydrologic connection from one side of the crossing to the other. This study investigated fish movement through road culverts in salt marsh creeks at several seacoast sites including the Wells NERR. Fish were collected upstream of tidally restrictive and tidally restored culverts, as well as in paired reference marsh creeks, in order to assess the effects of culverts on upstream nekton assemblages. Similar densities of fish were found throughout the marshes, although significantly lower densities of the sand shrimp (*Crangon septemspinosa*), were encountered. This may be evidence that culverts pose a migration barrier to shrimp. Fewer transient fish species were encountered upstream of culverts, suggesting that they impeded nekton movement. A study using a mark-recapture technique with the common mummichog (*Fundulus heteroclitus*) was carried out in tidally restricted, restored, and reference salt marshes to assess the impact of culverts on the mummichog's movement in creeks. Results indicate that small culvert size and increased water velocity considerably reduced rates of mummichog passage (Fig. 11-3), though decreased light intensity had no impact on movement. Eberhardt concludes that the presence of impounded upstream subtidal habitats, along with increased water velocity, may cause a drop in nekton movement between the downstream and upstream portions of the marsh creek, leading to segregated populations. Culvert restoration may lead to increased movement of resident fish, and ultimately an increase in fish production relay from salt marshes to coastal waters.

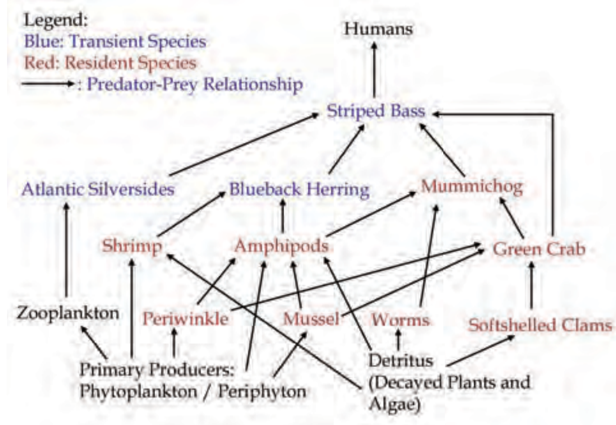


Figure 11-2: Food web indicating key species thought to be involved in trophic transfer of mercury (adapted from Chen *et al.* 2004).

Fish Utilization of Restored, Created and Reference Salt Marsh Habitat in the Gulf of Maine (Dionne et al. 1999)

Successful salt marsh restoration depends on adequate evaluation of restoration response. Fish utilization of restored and created marshes in New Hampshire and Maine (two created and four tidally restored marshes, including the Reserve's Drakes Island marsh) was compared to adjacent reference marshes. Fifteen fish and 4 crustacean species were collected from 13 marsh areas. This study provided the first density estimates for fish utilization of vegetated salt marsh habitat in the Gulf of Maine. The highest fish densities from this study (range 0.05 - 0.67 m^{-2}) just overlap with lower fish densities reported from more southerly marshes. Overall, fish were distributed similarly among manipulated and reference marshes, and fish distribution did not change with time. Trends in the data suggest that fish utilize a first category of marshes (elevated through deposition of dredge material and later restored by dug channels) to a lesser degree than impounded marshes (restored by culverts). It appears that fish will readily visit restored and created marshes in assemblages similar to those found in reference marshes over the short term (one to five years post-restoration), but are subject to the influence of differences in tidal regime, access to marsh habitat, and vegetation density. In the large majority of cases, hydrologic restoration of tidally restricted marshes will improve a much larger area of fish habitat per unit cost than creation of new marsh, and will not be subject to many of the constraints that limit the function of created

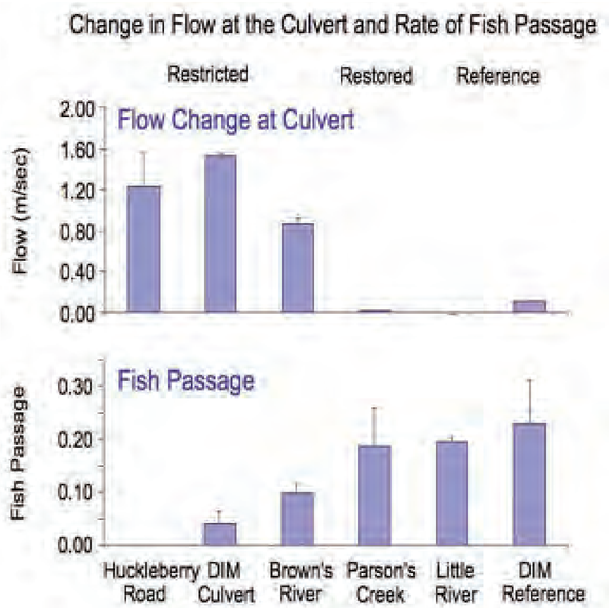


Figure 11-3: Inverse relationship between effect of culvert on water flow (culverts increase flow relative to the wider channel they constrict) and passage of fish through culvert. Reference site shows fish movement and flow change in an unrestricted channel (Eberhardt 2004).

marshes. The primary consideration in tidal restoration projects is not necessarily the cost of construction but the social, economic, and political issues that must be addressed. Often, tidally restricted marshes are located in highly developed coastal areas where many individual property owners may perceive the increased tidal flow as a threat, even when flood hazard studies show that no such threat exists. In spite of this caution, thousands of hectares of coastal fish habitat can be improved through a concerted program to restore the hydrology of tidally restricted marshes in the Gulf of Maine.

Dietary Habits of Benthic-feeding Fishes in a Southern Maine Salt Marsh: Evaluation of Prey Availability and Feeding Selectivity (Cartwright 1997)

Spatial and temporal factors affecting daytime benthic invertebrate and fish community structure and trophic patterns were investigated through several experiments in an unvegetated salt marsh creek channel of the Little River in Wells. Abiotic factors such as changes in salinity and seasonal temperature had significant influence on benthic invertebrate community structure. An increase of overall abundance of benthic organisms through the summer was observed, possibly showing a pattern of seasonal succession. Patterns of dominant species varied between upper and lower locations in the estuary.

Spatial and temporal patterns were observed in fish community abundance and diversity. In the lower portion of the estuary, species richness and evenness were the highest, due to the presence of marine species. Fish diets generally mirrored the findings of previous studies. Selectivity analysis of benthic prey revealed that most species exhibited a preference for one or two prey species (Fig. 11-4). This selectivity sometimes switched with prey abundance, which itself showed temporal and spatial variation. Within fish species, the size of the predator did not significantly influence the sizes of the major prey types eaten, but trends suggest that interspecific differences in predator size did play a role in prey size selection. Feeding patterns varied among fish species, with most species broadening their diet when benthic prey became less abundant, concurring with classic optimal foraging theory, while others did not. The dominant prey and niche overlap patterns of fish predators in the Little River estuary contrasted strongly with a previously studied marsh in mid-coast Maine (Lamborghini 1982).

A Comparative Study of the Ecology of Smooth Flounder (Pleuronectes putnami) and Winter Flounder (Pseudopleuronectes americanus) from Great Bay Estuary, New Hampshire (Armstrong 1995)

This study explored the relationship between two closely related species, the smooth flounder and winter flounder. Morphologically and ecologically they are both very similar on a large scale, and co-occur in estuaries from Labrador to Massachusetts. A three-year sampling program's results showed the two species were partially segregated along gradients of salinity and depth in the upper reaches of the Great Bay Estuary. The smooth flounder was most abundant in oligo-mesohaline riverine habitat and the winter flounder in the meso-polyhaline open bay habitat. With the seasonal increase in salinity, both species exhibited a generalized movement up-river. The distribution of smooth flounder along the depth gradient exhibited variation in age class with the smallest juveniles found at the shallowest depths. Intertidal mudflats served as significant nursery area for young-of-

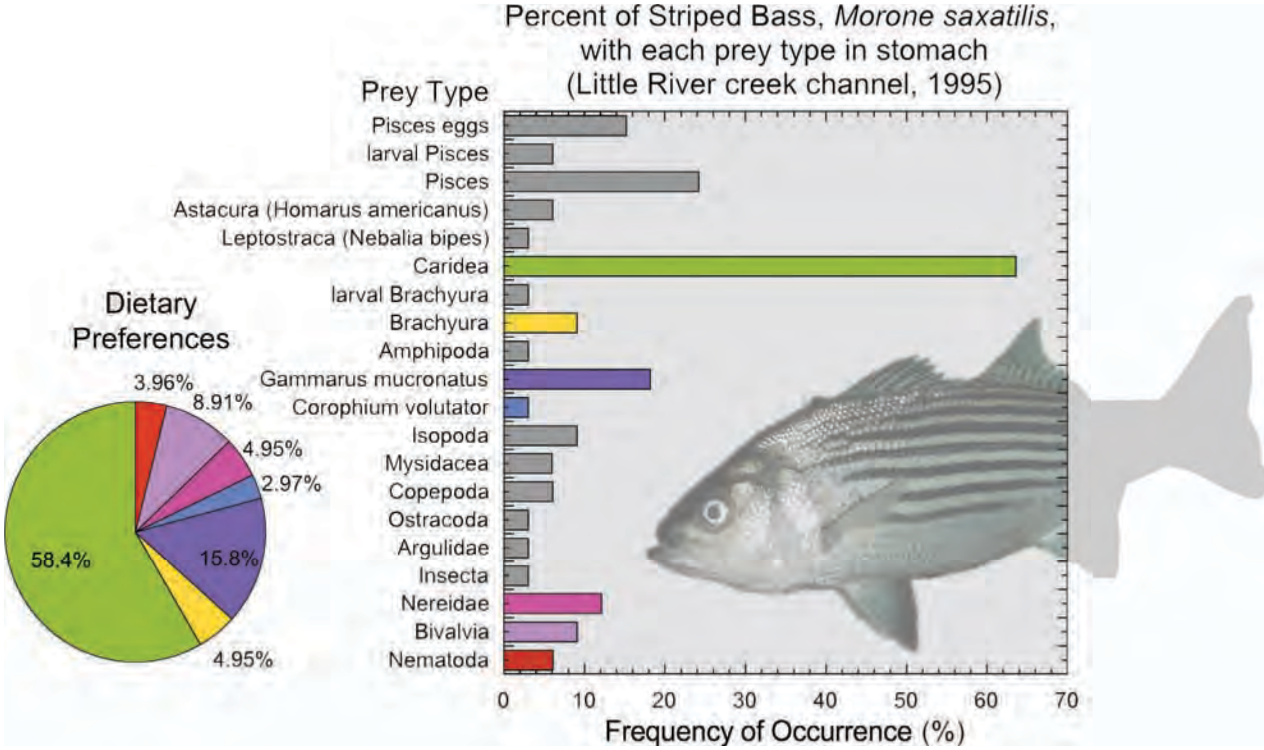


Figure 11-4: Summary and analysis of striped bass (*Morone saxatilis*) stomach contents. Data are pooled from various times in the summer, locations on the Little River, and size classes of bass. The pie chart displays values calculated using Chesson's index, which incorporates prey availability data in order to hypothesize the preferred food choice. See bar graph for species color code. Data from Cartwright 1997. Figure Hannah Wilhelm .

the-year smooth flounder but not for young-of-the-year winter flounder. Experiments in the laboratory and field showed that distribution of the two species in Great Bay was largely based on physiological constraints due to salinity. Growth and survival were optimal in particular salinities ranges (differing between species), and both species occupied sites along the salinity gradient that corresponded to their specific requirements. Seasonal changes in diet and habitat use were studied at several estuarine sites. Both species exhibited a greater overlap in diet than in habitat use. Their diet was similar and included polychaetes, bivalve siphons, and gammarid amphipods. Seasonal changes in prey abundance seemed to affect distribution of both species. Differences in diet reflected the disparity in benthic organisms at the estuarine sites. No evidence was found to indicate that food was a limiting factor to either species.

A survey of Meiobenthos and Ichthyoplankton in Two Contrasting Estuaries at the Wells National Estuarine Research Reserve (Wells NERR 1994)

The inlets of the Webhannet and Little Rivers lie 1.6 miles apart along the shore of the Wells Embayment. To investigate larval fish communities and linkages between the two estuaries and the bay, ichthyoplankton was sampled on 21 dates over an annual cycle (June 1992 – July 1993). Larvae of 17 fish species were collected, several of which were of recreational or commercial importance: Atlantic herring, Atlantic mackerel, lumpfsh, windowpane flounder, winter flounder, rainbow smelt, and Atlantic tomcod. Larvae of the sand lance, an important forage species, both for piscivorous fish and whales, were also present. Another group of species represented inhabitants of benthic rocky substrates present in the Wells Embayment: cottids (fourbeard rockling, grubby sculpin, longhorn sculpin), northern pipefish, and blennies (radiated shanny, rock gunnel, seasnail, and snake blenny). Fifteen of these species were present in Wells Embayment, 14 in the Webhannet River, and 4 in the Little River (sand lance, rainbow smelt, sea snail, and fourbeard rockling). Mean annual larval fish abundance in Wells Embayment was 1 m^{-3}, tenfold greater than fish abundance in the Webhannet River; Webhannet fish abundance was six-fold greater than Little River fish abundance. Greatest larval fish abundances were observed in late March and early April, with peak abundance in the Embayment at 14 m^{-3}, due to high numbers of sand lance. Temporal variation in fish abundance for the Webhannet reflected that for the Embayment, while the Little River showed no variation for most of the year (e.g. no larval fish present), with one peak in July 1992, coincident with a peak in Wells Embayment. The striking differences in larval fish fauna of the two estuaries invites further monitoring coupled with circulation modelling, to investigate biotic linkages between the Reserve's estuaries and the Gulf of Maine.

Comparison of Habitat Use by Estuarine Fish Assemblages in the Acadian and Virginian Zoogeographic Province (Ayvazian et al. 1992)

Species composition and habitat use of juvenile fishes was compared between the Webhannet estuary (toward the southern end of the Acadian biogeographic province) and Waquoit Bay (also a National Estuarine Research Reserve), at the northern limit of the Virginian province (Cowardin 1979). These sites bracket the biogeographic boundary of Cape Cod. Using seines for samples adjacent to marsh, and trawls for open water, 24 species of fish from fifteen families were sampled from the Webhannet; 48 species and 28 families were found at Waquoit. In the Webhannet, 90% of the population was composed of four species (ninespine stickleback, sand lance, mummichog and Atlantic silversides). At Waquoit, six species composed 90% of the population (mummichog, fourspine stickleback, tidewater silversides, rainwater killifish, and striped killifish). Adventitious southern and tropical species made up 6% of the catch at Waquoit, while none were present in the Webhannet. Density of fish was greatest adjacent to marsh for both sites, ranging from 65 – 361 • 100 m^{-2} in the Webhannet, and 15 fold higher at Waquoit, due in part to extremely high catches of mummichogs and Atlantic silversides that had shoaled in the marsh for protection on a single winter sampling date. As for fish life histories, 42% of the Webhannet fish individuals were residents, 21% were nursery species, 17% were migratory, and 17% were marine transients. At Waquoit, 33% of fish were residents, 23% were nursery, another 23% were marine transients, with migratory, adventitious and freshwater species comprising the final 20%. The differences between the sites are consistent with larger regional patterns of fish distribution and abundance between the Acadian and Virginian biogeographic provinces, supporting the presence of a biogeographic boundary at Cape Cod.

The Ecology of Estuarine Fishes in Southern Maine High Salt Marshes Access Corridors and Movement Patterns (Murphy 1991)

This study characterized the ecology of fishes utilizing the high marsh of the Webhannet and Little River estuaries during the summer. Ten of eleven species collected during the study used the intertidal creek for the major point of access to the high marsh. The common mummichog *Fundulus heteroclitus*, which made up the majority of the catch in numbers and biomass, used the marsh edge of the river channel as often as the creek in the Webhannet, while preference was given to the creek in the Little River. The movement patterns of mummichogs between salt marsh pools were investigated using a mark-recapture technique. Only 4% of the fish were recaptured in new locations. This suggests the existence of some type of fidelity to home pools, in these two estuaries.

Seasonal Abundance, Temporal Variation and Food Habits of Fishes in a Maine Salt Marsh Creek System (Lamborghini 1982)

Seasonal occurrences, abundance, patterns of activity and food habits of fishes were investigated in a mid-coast salt marsh creek. Twenty-one species total were collected with spring and summer showing the greatest number of species, and late summer showing the highest number of individuals (Fig. 11-5). Specimens smaller than 150 mm total length comprised the majority of the catch and were adults or juveniles of inshore fishes, and juveniles of larger marine fishes. Dominant species changed with the seasons.

The fishes could be divided into four groups: residents, nursery species, diadromous species, and sporadic visitors. This division was based upon seasonal abundance, length frequencies, stomach contents and occurrence

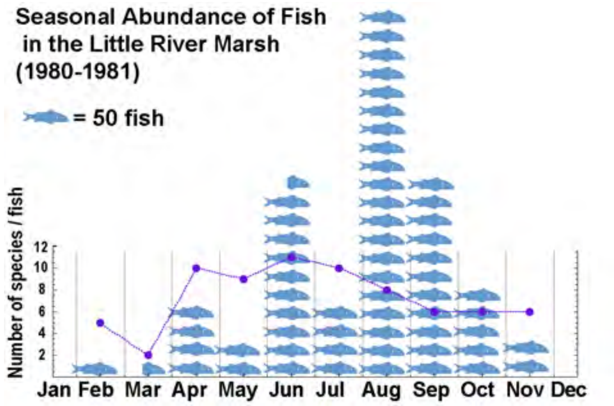


Figure 11-5: Seasonal abundace of fish in the Little River marsh by species (line) and total number of individuals (fish shapes). Data from Lamborghini 1982. Figure Hannah Wilhelm.

on tide movement. Resident species, which peaked in fall, formed the numeric majority. The number of sporadic visitors peaked in spring. Nursery species were found nearly year round, but especially during summer. Diadromous species were observed primarily in summer. Adult residents were observed to move into the marsh in spring whereas young-of-the-year appeared to exit the marsh in summer and fall. Resident species were collected both day and night, while non-residents were found in much greater numbers, or exclusively, at night. Twelve of the twenty-one species were studied for food habits revealing that they were all carnivorous, feeding heavily upon crustaceans. They could be divided into three foraging groups: zooplanktivores, benthic carnivores and mid-water predators. The marsh creek system provided nursery area for resident, diadromous, and marine species.

Summer Distributions of Demersal Finfish in the Montsweag Brook Estuary, Maine (Yoder 1973)

This study was carried out to determine distribution of finfish species as affected by temperature, salinity, and to determine the general summer demersal (i.e., bottom water) fish distributions within the estuary. The estuary is very small with an attendant salt marsh. It was dominated by mud substrate, which contrasts with the coarse substrates of the Bay and Back River to which it is a tributary. The Montsweag Bay-Back River area was home to a nuclear-powered generating station (now dismantled). Concerns arose over the impact of thermal effluent on the estuarine environment. Sampling occurred for two consecutive summers. Nine demersal species were collected with six of the nine species having comprised nearly the entire catch. Either an especially rainy summer or artificial warming of adjacent bay waters, or both, contributed to elevated water temperatures in the later summer. This summer of warmer water coincided with a modified distribution of the six major demersal species. The alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) seemed to have benefited (numbers increased from previous year) whereas Atlantic tomcod (*Microgadus tomcod*), smooth flounder (*Pleuronectes putnami*), winter flounder (*Pseudopleuronectes americanus*) and white hake (*Urophycis tenuis*) were adversely affected by the increase in water temperature (numbers decreased from previous year).

The Pelagic and Demersal Finfish of the Montsweag Brook Estuary (Yoder 1972)

Through a variety of sampling techniques, this study was conducted to survey pelagic and demersal fishes in the Montsweag Brook estuary (see above description of the site). This study also addressed concerns about the impact of thermal effluent on fish populations. The four most abundant pelagic fishes, sampled by gill nets, were first the alewife (*Alosa pseudoharengus*), second the Atlantic menhaden (*Brevoortia tyrannus*), third the rainbow smelt (*Osmerus mordax*), and lastly the blueback herring (*Alosa aestivalis*). The four most abundant demersal fishes, sampled by fyke nets, were the Atlantic tomcod (*Microgadus tomcod*), the smooth flounder (*Pleuronectes putnami*), the winter flounder (*Pseudopleuronectes americanus*), and the white hake (*Urophycis tenuis*). The low numbers or absence of certain species may have been due to the timing of sampling or the rarity of the species in the area. Beach seining yielded common estuarine species such as mummichogs and sticklebacks, as well as some northern pipefish (*Syngnathus fuscus*) and juveniles of pelagic and demersal species.

Feeding Chronology and Food Habits of the Tomcod (Microgadus tomcod) and Winter Flounder (Pseudopleuronectes americanus) in Montsweag Bay (Sheepscot River) (Alexander 1971)

This study investigated the effects of tide and length of daylight on the chronology of feeding behavior and food habits of tomcod and winter flounder in Montsweag

Bay, Maine. Daylight hour sampling occurred three times a day (morning, midday, and evening) at 2-3 day intervals over nearly one-half of the lunar month for consistent sampling of each stage of tide at each time of day. Sampling occurred in the second half of July. Approximately 30 fish were collected per sample and an index of stomach fullness was used to measure variation in feeding intensity. Effects from tide, or photoperiod-tide interaction, were not observed in either species. Tomcod exhibited a peak of feeding activity, or period of intensive feeding, in the early morning with little activity for the rest of the day. Tomcod fed mostly on crustaceans (e.g. sand shrimp, *Crangon septemspinosus*) followed by polychaete worms (e.g. sand worm, *Neanthes virens*). Winter flounder showed feeding activity throughout the day with no definite peaks and fed primarily on polychaetes, followed by mollusks and crustaceans, largely consistent with other food habit studies for this species.

Species Accounts[1]

To complement the data summarized above from studies of fish ecology in the estuaries of Wells NERR and other Gulf of Maine marsh-estuarine ecosystems, we provide brief accounts for a selection of species. Species were chosen to represent different life histories (resident, migratory, marine transient), importance (economic, forage) or notability. Fishes were sampled using a variety of methods, including a weir (pictured).

Alewife

The **alewife,** *Alosa pseudoharengus* (Fig. 11-6), is an anadromous herring species that can be found in many coastal rivers of the Gulf of Maine. Their average size is 10" – 11" (25 – 28 cm), but they can grow up to 15" (38 cm) long. Most alewives weigh 8 – 9 ounces (230 – 255 g). Alewives use a full range of habitats from fresh water to the edge of the continental shelf. They spend most of their lives at sea and travel back to fresh water to spawn in ponds and slow moving streams. Spawning occurs from late April and early May through June in the Gulf of Maine. Females deposit from 60,000 to 100,000 eggs or more, which cling to twigs, rocks, or detritus. After alewives hatch and grow for a month in fresh water, they successively move downstream in schools numbering in

Figure 11-6: Alewife, *Alosa pseudoharengus*. © James Dochtermann.

the thousands throughout the summer, making the journey to the ocean by fall. The schools migrating back to freshwater have equally large numbers of fish. Alewives feed on copepods, amphipods, mysids, shrimp, fish eggs, and smaller fish such as eels, sand lance, herring, cunners, and even their own species. After spawning, they depend on the abundant shrimp in estuaries. Eels and perch prey on juvenile alewives, while striped bass and salmon eat spawning adults. Fishermen catch them in weirs in the lower reaches of streams (or in gill nets in outer waters).

The alewife is a species of special historical significance. Early coastal settlers compared them to Atlantic herring and enjoyed an abundance of this fish heading upstream every spring. Native Americans taught the first colonial settlers in New England to plant alewives with crops for fertilizer. Today they are almost exclusively used for lobster bait or processed into pet food and fertilizer.

Alewife populations have fallen in the last few centuries and their range restricted, primarily a result of loss of access to spawning habitat and inadequate streamflow. They are still seen in large numbers in other coastal waterways. Initial restoration efforts have met with success, due to the alewife's resiliency and their ability to quickly discover restored fish passageways.

The alewife is an important forage fish and the only known host for the "Alewife Floater," *Anodonta implicate*, a species of freshwater mussel.

American Eel

The **American eel**, *Anguilla rostrata* (Fig. 11-7, and photo), is a catadromous species found throughout the the Gulf of Maine and its tributaries. Young-of-the-year "elvers" average 2 – 3.5 in (5 – 9 cm), and adult eels can

1 Primary source for this section is Bigelow and Schroeder (1953). Updated information is available in the most recently revised Edition: Collette and Klein-MacPhee (2002).

A weir was used to survey fish use of the Little River on a daily basis. Photo Michele Dionne.

Elver. Photo James Dochtermann.

grow to 4 ft (122 cm) long. Some elvers remain in tidal marshes, river mouths or bays behind barrier beaches, while others head into freshwater, ascending large rivers. They are very temperature tolerant. Larger (adult) eels are famous for being found in nearly every aquatic habitat known to have any sort of connection to the ocean, and can over-winter in mud. Eels spawn in midwinter. From December to January, they transform into elvers and head toward inshore waters. The migration ends in the mouths of New England streams and rivers by the following spring. There are four stages in their life cycle: 1) leptocephalus, 2) glass eel, 3) yellow eel, 4) silver eel. Eels live as free-floating larvae ("leptocephali") before they metamorphose into "glass eels" (which can swim) and head toward the coast. They appear along our shores in the spring and enter estuaries where they become known as "elvers" (pictured). During the following "yellow eel" stage, males generally remain in estuaries for a few years and females venture into freshwater, often long distances, and can remain there for 10 – 30 years before migrating out to spawn. As they reach sexual maturity known as the "silver eel" stage, the eels that are in fresh water head downstream in the fall, traveling mostly at night. They then make the long journey back to their natal waters in the Sargasso Sea (near Bermuda) to deposit their eggs, which float in the upper water layers until hatching. Eels die after spawning, though the final stages of the eel's life cycle are still not well documented.

Eels eat mostly plankton during the larval stage, but as juveniles and adults they become carnivorous and also feed on dead fish and other detritus. They are primarily nocturnal feeders. While in salt or brackish water, they feed on small fishes, crabs, lobsters and other crustaceans. In fresh water, they feed on worms, snails, aquatic insect larvae, crayfish, small fishes, and frogs. They cease feeding when they reach sexual maturity. Many predators eat eel larvae and elvers. Adult eels are eaten by sharks and swordfish in the ocean and are caught by anglers in fresh water.

The numbers of American eel have been in decline due to over-fishing, pollution and restriction of access to freshwater habitat by dams.

Figure 11-7: American eel, *Anguilla rostrata.* © James Dochtermann

Atlantic silverside sampled from a Casco Bay fringing marsh. Photo Cayce Dalton.

Atlantic Tomcod

The **Atlantic tomcod,** *Microgadus tomcod* (see photo), is a bottom-dwelling member of the cod family. Adults average 9" – 12" (23 – 30 cm) long. They are year-round residents of estuaries, frequently inhabiting salt marsh channels, mouths of streams, and sometimes eel grass beds. Considered an anadromous species, tomcod migrate upriver to spawn in the shallow brackish water of estuaries from November through February, peaking in January. Spawning occurs over gravelly bottoms and sand; eggs sinking to the bottom in masses. Incubation takes 24 – 30 days at temperatures of 30 – 43˚F (4 – 6˚C). Young-of-the-year may remain in brackish water for the first spring and summer of their lives.

Adults are known to feed on their own eggs, larvae, and juveniles during winter and spring. They also eat small crustaceans, worms, small mollusks, squid, and fish larvae. Larval tomcod eat mostly copepods. At 1 to 2 years old, tomcod primarily eat amphipods and decapods. Yearling striped bass and bluefish prey on tomcod. Tomcod produce antifreeze proteins, which enable them to tolerate water temperatures below freezing. The protein is similar to that found in some arctic and antarctic fishes. They are resistant to sudden changes in temperature and salinity.

The story of the demise of tomcod populations is probably the same as with all anadromous fishes: loss of access to spawning grounds, over-fishing and exposure to pollutants.

Atlantic Silverside

The **Atlantic silverside,** *Menidia menidia* (Fig. 11-8, and photo), are an abundant, pelagic, year-round resident in coastal shores, bays, river mouths, salt marshes, and brackish waters. Adults average 4.5 in (11.4 cm) long. Young fish are found in estuaries in a range of intertidal and subtidal habitats, and in deeper near-shore waters with sandy bottoms, shell beds, eel grass and sea lettuce. Spawning occurs from May though early July in southern New England, possibly later in the Gulf of Maine. Atlantic silversides gather in schools to spawn,

Atlantic Tomcod. Photo James Dochtermann.

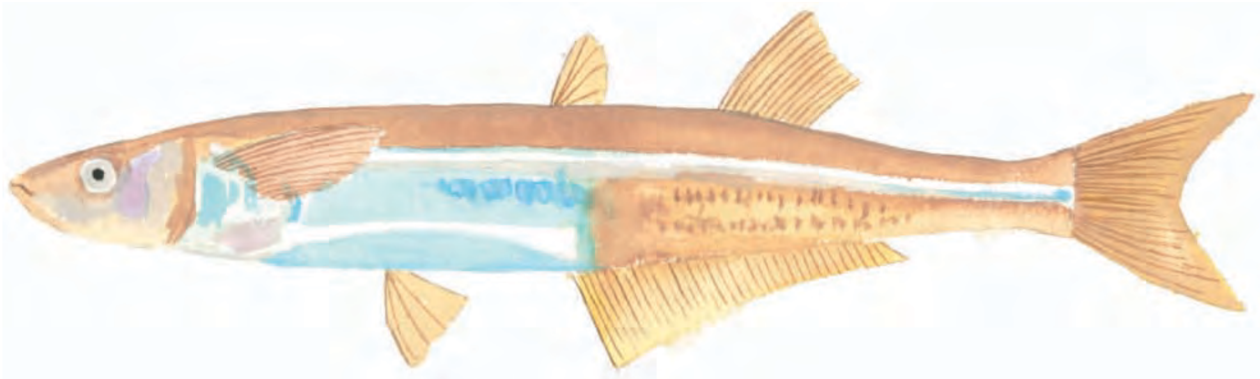


Figure 11-8: Atlantic silverside, *Menidia menidia*. © James Dochtermann

and lay eggs on sandy bottoms or in marsh grasses at high tide. The eggs quickly sink and stick to the substrate in ropy clusters or sheets.

The Atlantic silverside is omnivorous; feeding on copepods, amphipods, mysids, shrimps, juvenile squid, mollusk larvae, small marine worms, fish eggs, fallen insects, algae and diatoms. They are a forage fish for striped bass, bluefish and mackerel, and prey for sea birds.

Mummichog

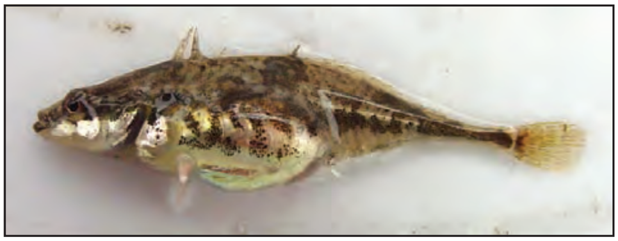
The **mummichog**, *Fundulus heteroclitus* (see photo), is without doubt the most abundant resident marsh-estuarine fish species in the Gulf of Maine. Adults average 3.5 in – 4 in (9 – 10 cm) long. They are found in sheltered shores among eelgrass and salt hay flooded by high tides, in salt marsh tidal creeks, and in brackish streams. At ebbing tides, they can become concentrated in marsh pools where they tolerate low dissolved oxygen, high carbon dioxide, high temperatures, and a wide range of salinities. In the winter they move to deeper areas, sometimes burrowing in the mud, but mummichogs are not likely to move out to Gulf waters. Spawning occurs from early spring to summer. Sexual maturity is reached at 1 – 2 years. The males, brilliantly tinted at sexual maturity, court the females and drive off rivals. They spawn in a few inches of water, the male clasping the female behind the anal and dorsal fins, usually pressing against a stone or the bottom. Their tails vibrate rapidly while the eggs and milt are released. The eggs, colorless and surrounded by a firm capsule, sink and clump together or stick to anything they fall upon. Incubation lasts 9 to 18 days and the larvae are about 0.25 in (7 mm) long at hatching. Many young-of-the-year remain in marsh pools during the first summer.

Mummichogs are omnivorous, eating mostly eelgrass and other vegetable matter, as well as shrimp and other tiny crustaceans, mollusks, and insect larvae. They will also gather around and feed on dead fish. During spawning they sometimes eat their own or each other's eggs. Mummichogs are eaten by surface-feeding birds such as egrets, common terns, herons and king fishers; mammals, and large predatory fish such as striped bass and brook trout.

Fourspine Stickleback

The **fourspine stickleback,** *Apeltes quadracus* (Fig. 11-9, and photo), is a year-round resident commonly found among mummichogs and other sticklebacks in estuaries. Similar to the threespine, they move into fresh water but are known to be more of a brackish and salt water fish; they never move very far inland or offshore. Adults

Mummichogs. Photo James Dochtermann.



Fourspine stickleback. Photo James Dochtermann.

average 1.5 in – 2.5 in (3.8 – 6.3 cm) long. Spawning occurs from late May through early July. Males build nests in intertidal areas with aquatic vegetation. When females enter their territory, the males prod them and then swim to the nest. Females eventually enter the nest site and deposit their eggs. Larvae are about 4.5 mm long. Fourspine live for about one year, but some may reach two.

Fourspine sticklebacks are omnivorous with a diet mainly consisting of copepods and other small crustaceans. They are eaten by the American eel, tomcod, killifish, and other sticklebacks, including their same species; and birds such as common terns, kingfishers, and egrets.

Ninespine Stickleback

The **ninespine stickleback**, *Pungitius pungitius* (Fig. 11-10, and photo), is a benthopelagic species (living and feeding near the bottom, and in the water column) found in freshwater, brackish, and marine habitats. Adults average 2 – 2.5 in (5.1 – 6.3 cm). They commonly share shallow estuaries and tidal marsh pools with the threespine stickleback, preferring areas of dense weed cover. Freshwater populations prefer shallow, vegetated parts of ponds, lakes, and pools or slow streams; and sometimes occur over sand. Marine populations are found near shore and might exhibit a seasonal migration, offshore in the fall to deeper water, and inshore in the spring to spawn. They are the most abundant of the four stickleback species occurring at the Wells NERR.

Spawning occurs from spring to summer. Considered by some to be anadromous, they spawn upriver in freshwater regions, but sometimes just above the head of tide or in brackish water. Males build a nest, attached to grasses or weeds where the females spawn, and guard the nest until eggs hatch in 5 – 12 days. Eggs are semi-buoyant, and

Ninespine stickleback. Photo James Dochtermann.

a relatively turbulent current may be needed in order to prevent the eggs from settling and being silted over. They live one to two years.

Ninespine sticklebacks eat mostly small crustaceans and aquatic insects; also eggs and larvae of their own species during spawning season, and eggs and young of other fish. Tomcod, Atlantic cod, silver hake, and larger striped

Figure 11-9: Fourspine stickleback, *Apeltes quadracus*. © James Dochtermann

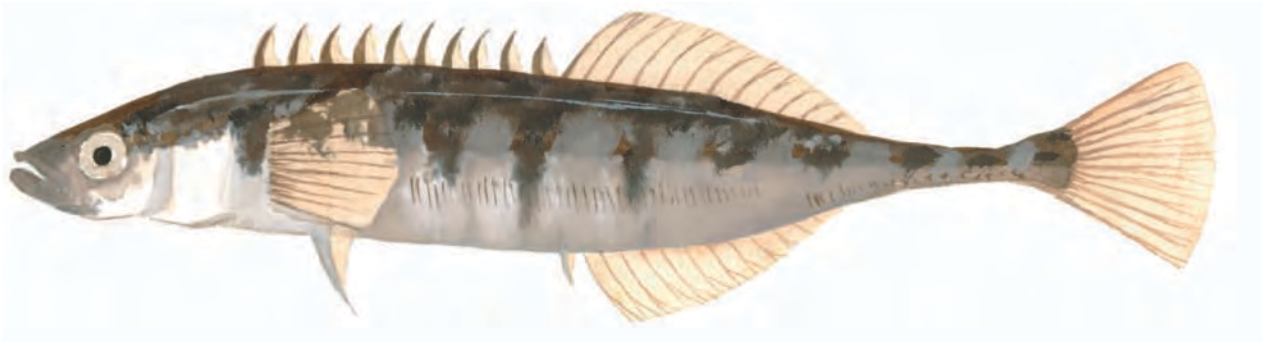


Figure 11-10: Ninespine stickleback, *Pungitius pungitius.* © James Dochtermann

bass may prey on juveniles. Adults seem to have fewer predators though are eaten by common terns, kingfishers, and egrets.

Rainbow Smelt

The **rainbow smelt**, *Osmerus mordax* (Fig. 11-11), is a pelagic species found in freshwater, brackish and marine habitats with a depth range to 150 m. Adults average 7 – 9 in (18 cm – 23 cm) long, weighing 1 – 6 ounces (28 – 170 g). As an inshore fish, many reside in estuaries when not spawning. Antifreeze activity has been detected in their blood, enabling them to spend winters near shore in freezing temperatures. Spawning occurs from early March through April. The rainbow smelt is anadromous, beginning spawning migration in early March once ice melts and the water temperature rises to 40°F (5°C). They spawn in fresh water brooks and streams, or in slightly brackish water below head of tide, but generally do not journey far upstream. Eggs are very small and adhesive, sticking to gravel, rocks, plants, sticks, and other eggs. Adult smelt return to salt water immediately after spawning to spend the summer either in the estuary or out at sea.

Both adults and juveniles are schooling fish and voracious predators. Adults feed mostly on small crustaceans, such as shrimp and mysids, and small fish such as sticklebacks, alewives, and silversides. Marine worms, shellfish, crabs, and squid have been found in their stomachs. They fast during spawning runs to fresh water. Juvenile smelt depend on copepods and other small pelagic crustaceans. An important forage fish, smelts are eaten by their own species and larger fish. They are also eaten by seals and by birds such as mergansers, cormorants, terns, and gulls.

The rainbow smelt recreational fishery is regulated by the Maine Department of Marine Resources. When they swim to natal streams to spawn in the spring, fishermen use dip nets to catch them. In winter, anglers fish for smelt through the ice on Maine's tidal rivers and saltwater bays. They are a regional seasonal delicacy. They once supported a large commercial fishery in the Gulf of Maine. Over the last 50 years, however, their streams

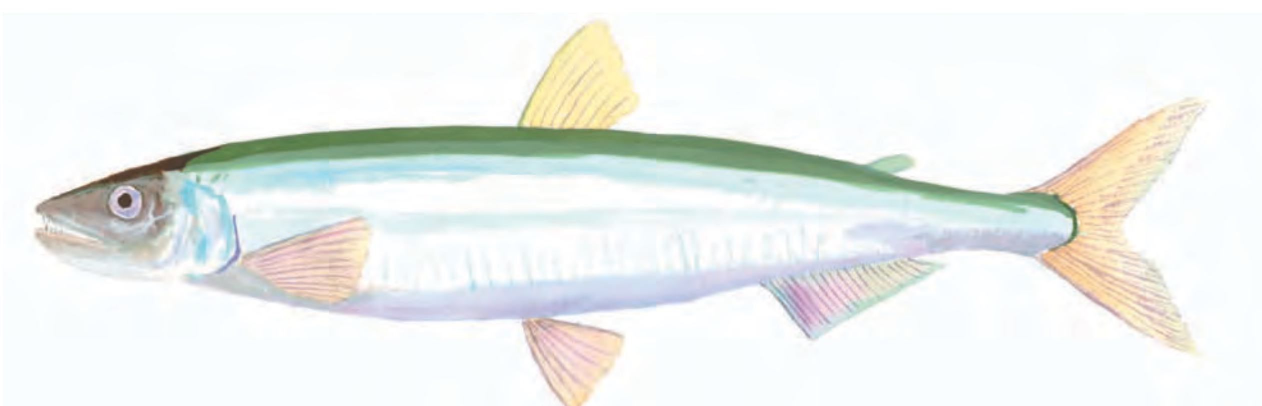
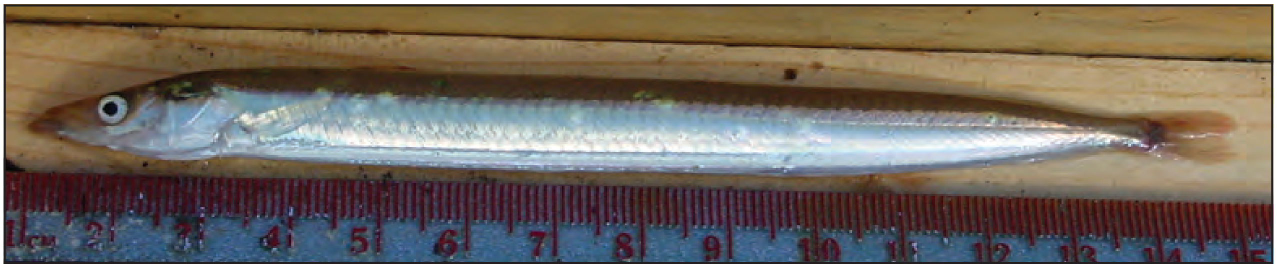


Figure 11-11: Rainbow smelt, *Osmerus mordax*. © James Dochtermann



Sand lance. Photo James Dochtermann.

have been obstructed or polluted, leading to the demise of this important local fishery.

Sand Lance

The **sand lance**, *Ammodytes americanus* (Fig. 11-12, and photo), is a pelagic, marine species found at river mouths, harbors, and estuaries, but also over offshore banks. Adults are 4 to 6 in (10–15 cm) long. Sand lance divide time between the water column and bottoms of fine gravel or sand, avoiding substrates of silt or mud. They bury themselves during periods of low light, during dormant periods, and sometimes in response to predators. They tolerate a range of temperatures and salinities. Spawning occurs from December to February. Sand lance often form large, dense schools, sometimes with herring. They may become inactive or hibernate while buried in winter. Sand lance mature in 2 years. Females spawn *en masse* once a year. Their adhesive eggs remain on the bottom, sticking to grains of sand. Incubation period varies with temperature and oxygen level, and may range from 2 to 9 weeks. Sand lance can live several years.

Adult sand lance prey upon copepods, chaetognaths (arrow worms), larval fish, and a variety of other animals. Small larvae eat phytoplankton, diatoms, and dinoflagellates, then graduate to copepod larvae and euphausiids (type of krill). Sand lance feed during the day, perhaps especially in morning and evening. The sand lance is an important forage species (perhaps critically important) for seabirds, fishes such as cod and yellowtail flounder, and marine mammals including the North American right whale.

Winter Flounder

The **winter flounder**, *Pseudopleuronectes americanus*, is a demersal (bottom-dwelling) flatfish that lives in marine habitats preferring substrates of sand, silt, or mud. Generally adults are from 12 - 15 in (30.5 - 38 cm) in length and 1.5 - 2 lbs (680 - 907 g) in weight. It can be found moving up to brackish water of river mouths and estuaries, salt marshes, bays, and in nearshore and offshore waters. The range of water temperature tolerance for adults appears to be from around 30 - 66°F (-1.1 - 18.8 °C). Its distribution is spread across a wide spectrum of temperatures at each season, from the near freezing point of saltwater (in Canadian waters—and which can occur in shallower parts of the Gulf of Maine in late winter), to 64°-66°F (17.7°-18.8°C; in the southwestern part of the Gulf of Maine in summer) to possibly 70°F (21.1°C) in the southern part of its range.

Spawning occurs from January to May. Most winter flounder reach maturity after about 2.5 - 3.5 years. They spawn on sandy substrate often in nearshore waters as shallow as 1 to 3 fathoms (1 fathom = 6 feet or 1.83 meters), but also in deeper offshore waters as deep as 25 to 40 fathoms on George Bank. Spawning occurs when water temperatures reach the coldest range of the year, about 31°-35°F. In the inner parts of the Gulf of Maine, most eggs are produced in water with salinity from about

Figure 11-12: Sand Lance, *Ammodytes americanus*. © James Dochtermann

Winter flounders from a salt marsh creek, York River. Photo James Dochtermann.

31 – 32.3 mg L^{-1}. Some are known to spawn in estuaries but do so in brackish water with salinity around 11 mg L^{-1}. Egg incubation lasts 15 – 18 days at a water temperature of 37°-38°F. Winter flounder larvae are common near the mouths of estuaries. They are pelagic to 8 – 9 mm long, by which time the right eye has migrated and the small fish settle on the bottom, roughly six weeks after hatching. Winter flounder (see photo) use marsh-estuarine habitat as nurseries during their first growing season in the Gulf of Maine.

The adult winter flounder's small mouth limits what it can eat to small invertebrates and fish fry. Common invertebrates that are included in the winter flounder's diet include shrimp, amphipods, small crabs, or other crustaceans; sometimes ascidians, sea worms (*Neanthes* spp.), or other annelids; and bivalve or univalve mollusks. Cormorants and large heron prey on winter flounder; common terns feed on juveniles. The flounders are the flat chameleons of the estuaries and sea, able to change color to blend in with the bottom, awaiting the arrival of prey, and hiding from predators.

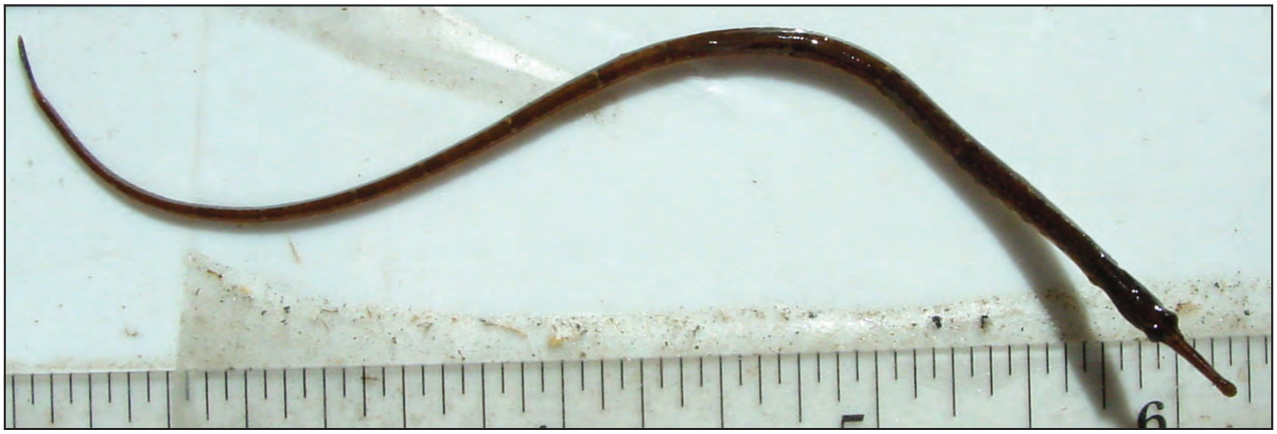
The winter flounder fishery is managed under the New England Fishery Management Council's Multi-species Fisheries Management Plan (FMP); and is the most highly sought-after flatfish by recreational anglers. Flounder fishing is a popular activity from boats, piers, and bridges along the Gulf of Maine's tidal rivers, estuaries, bays, and harbors. Many anglers attest that the flounder have "disappeared," or numbers have drastically declined, from coastal waters throughout New England.

Northern Pipefish

The **northern pipefish**, *Syngnathus fuscus* (Fig. 11-13, and photo), can be found in marine or brackish waters, among eelgrass or seaweed in shallow bays, salt marshes, harbors, creeks, and river mouths. Pipefish are often found under floating rockweed along the Maine coast. They can tolerate a salinity range of 0 – 38.8 PSU, and temperature range of 37°–95°F (3°–35°C). Adults are rarely longer than 8 in (20.8 cm). They are commonly found in the intertidal zones of estuaries. It is believed that the pipefish migrate inshore-offshore seasonally, moving from estuaries in the spring and fall, to near-shore continental shelf waters in September and October. Spawning occurs from March to October. Males carry the eggs, with a brood pouch capacity of 104 – 570 eggs. The female inserts her protruding oviduct into the opening of the male's pouch to transfer one dozen or more eggs at a time, in succession, until the pouch is filled. It is believed that fertilization takes place during the transfer of eggs. Larger males hold two to four rows in two or three layers on each side of the pouch. Incubation takes about 10 days. The young remain in the pouch until they are 8–12 mm long, and are ready to leave the pouch and live independently. Sexual maturity is reached around one year.

The pipefish are diurnal (daytime) feeders, eating mostly copepods, amphipods, fish eggs, and very small fish larvae,

Figure 11-13: Northern Pipefish, *Syngnathus fuscus*. © James Dochtermann.



Northern Pipefish, Little River at Wells NERR. Photo James Dochtermann.

polychaete worms, and mysid shrimp. They are eaten throughout their range by fishes, including the smooth dogfish (*Mustelus canis*), cod (*Gadus morhua*), sea raven (*Hemitripterus americanus*), black sea bass (*Centropristis striata*), weakfish (*Cynoscion regalis*), oyster toadfish (*Opsanus tau*), and bluefish (*Pomatomus saltatrix*).

Striped Bass

The **striped bass**, *Morone saxatilis* (see photo), is a demersal species found in freshwater, brackish, and marine habitats. With the exception of breeding season, striped bass are usually found along the coastline in bays, small marsh estuaries, in river mouths, and off the open coast; younger ones tend to school. The majority of large bass (30 lbs or 13.6 kg or larger) are found on the open coast along sandy beaches, among rocks and boulders, and at estuary mouths. Striped bass are known to school, moving along the coast within the same general environs during the summer. They are active until the temperature falls below 43˚F (6˚C) when they leave for warmer offshore waters or loll at the bottom of an estuary in a dormant state. Adults weigh from 3 – 35 lbs (1.4 – 15.9 kg). A 20 lbs (9 kg) bass averages 36 in (91.4 cm) long. Females grow larger than males.

The striped bass is an anadromous species, migrating to spawn in brackish water at the mouths of estuaries or upriver in fresh water. Spawning occurs from May to July. The water must be turbulent enough so the eggs will not settle on the bottom where they could be smothered. Females can deposit from ten thousand to one million semi-buoyant eggs that tend to drift downstream with the current. Eggs hatch in 4 to 10 days in water temperatures of 58˚–60˚F (14˚–16˚C). Larvae form small schools

A young Striped Bass or "schoolie," Little River, Wells NERR. Photo James Dochtermann.

and move inshore. Juveniles move down river into waters of higher salinity during their first summer. Females mature at 4 to 5 years and males mature at 2 to 3 years.

The striped bass is a carnivorous species that feeds on smaller fish and a variety of invertebrates, including herring, smelt, sand lance, eels, silver hake, squid, crabs, lobsters, and sea worms. In the 1970's and 1980's there was a significant decline in recreational and commercial landings of striped bass, attributed to over-fishing and poor water quality in spawning habitats. Striped bass are managed under the Atlantic States Marine Fisheries Commission. In 1995, Atlantic striped bass were declared a restored stock and restrictions were somewhat relaxed. Due to this resurgence in numbers, "stripers" persist as one of, if not the, most sought-after coastal fishes in the Gulf of Maine for recreational angling, whether by lures, bait or flies.

Human Influences

The offshore commercial ground fisheries in the Gulf of Maine have been in decline for decades (Mayo and Terciero 2005), attributed to a combination of over-fishing, habitat alteration by fishing gear, and changes in food web structure due to species and size selective harvest and bycatch. In response to this decline, the National Marine Fisheries Service now incorporates habitat information and ecological processes into its predictive management models (Busch *et al*. 2003). Much less is known about the status of coastal fisheries in Maine, other than to observe that with the exception of Atlantic herring, many finfish species are no longer abundant enough to support viable commercial day fisheries. Beginning in 2000, Maine and New Hampshire began a collaborative inshore trawl survey to assess the status of coastal finfish populations. Prior to that time, concerns about the fixed-gear fishery (e.g. lobster) prevented fisheries-independent research trawling in coastal waters. With four years of spring and fall surveys completed, enough data are available to begin stock assessments (Sherman *et al*. 2005). The coastal lobster fishery, in contrast, has continued to grow, apparently subsidized by the great biomass of finfish bait that is consumed by lobsters that escape from baited traps (Grabowski *et al*. 2005). The structure of the coastal food web has been clearly modified through human action, but little is known about the causes and consequences of this change, or of the interaction between coastal and offshore food webs. In marsh-dominated estuaries, the most obvious human influences involve alterations of hydrology through increased runoff from shoreland development, tidal restrictions created by roadways and culverts, and inlet dredging.

Research Needs

Although we know more about marsh-estuarine fish communities in the Gulf of Maine than was known a decade ago, we still lack an understanding of the role of marsh-estuarine ecosystems in supporting coastal food webs and Gulf of Maine fish populations. We suggest the following broad lines of research to improve our understanding. These topics apply equally well to back-barrier and fringing marsh habitats.

◊ Investigate linkages between larval, juvenile and adult fish species in marsh-estuarine ecosystems and Gulf of Maine nearshore waters.

◊ Investigate importance of marsh resident fish species as forage for marine transients.

◊ Investigate food web transfer of energy from marsh-estuarine primary producers.

◊ Investigate role of the non-native green crab in marsh-estuarine food webs.

◊ Investigate relationship between fish community structure / diversity and salt marsh hydrology, geomorphology and geography.

◊ Investigate ecosystem level functions related to marsh-estuarine fish community structure and biodiversity.

Management Recommendations

Although vegetated salt marsh is now reasonably well protected against drastic insults such as large-scale dredging and filling, this type of impact continues on the small scale (e.g. docks, roadwork, bulkheads). Surprisingly, there is no assessment of the cumulative loss of salt marsh habitat and associated ecological functions (Dionne et al. 1998). To properly assess these losses, fringing marsh habitat would need to be mapped statewide. In addition, increasingly intense development in adjacent upland is rapidly reducing the ability of shoreland buffers to protect salt marshes from stormwater, and the nutrients and contaminants it often delivers to salt marshes and other intertidal habitats. Development of the shoreland zone will also hinder salt marsh-upland transgression in response to sea level rise. Finally, a specific site selection plan is needed to guide the restoration of hydrologically altered marshes in Maine. We recommend that relevant state agencies (State Planning Office, Department of Environmental Protection, Department of Marine Resources, Department of Transportation) initiate collaborative programs to improve the protection and restoration of coastal marshes from these pressing human influences.

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Table 11-2: Fish found at Wells NERR. Sources: Fish of the Wells National Estuarine Research Reserve (Checklist), 2002, Casco Bay 2002-4, NEC Project 2002-3, NOAA Project 2005-6
* These species have been found in Gulf of Maine nearshore habitats adjacent to Wells NERR estuaries.

Family	Common Name	Scientific Name
Myxinidae (Hagfishes)	Hagfish	*Myxine glutinosa**
Petromyzontidae (Lampreys)	Sea Lamprey	*Petromyzon marinus*
Squalidae (Spiny Dogfishes)	Spiny Dogfish	*Squalus acanthias**
Rajidae (Skates)	Thorny Skate	*Amblyraja radiata**
Anguillidae (Freshwater Eels)	American Eel	*Anguilla rostrata*
Clupeidae (Herrings)	Blueback Herring	*Alosa aestivalis*
	Alewife	*Alosa pseudoharengus*
	American Shad	*Alosa sapidissima*
	Atlantic Menhaden (Pogy)	*Brevoortia tyrannus*
	Atlantic Herring	*Clupea harengus*
Salmonidae (Trouts)	Atlantic Salmon	*Salmo salar*
	Brown Trout	*Salmo trutta*
	Brook Trout	*Salvelinus fontinalis*
Osmeridae (Smelts)	Rainbow Smelt	*Osmerus mordax*
Gadidae (Codfishes)	Atlantic Cod	*Gadus morhua*
	Fourbeard Rockling	*Enchelyopus cimbrius*
	Atlantic Tomcod	*Microgadus tomcod*
	White Hake	*Urophycis tenuis*
	Red Hake	*Urophycis chuss*
	Silver Hake	*Merluccius bilinearis**
	Cusk	*Brosme brosme**
	Pollock	*Pollachius virens*
Cyprinodontidae (Killifishes)	Common Mummichog	*Fundulus heteroclitus*
	Banded Killifish	*Fundulus diaphanus*
	Striped Killifish	*Fundulus majalis*
Atherinidae (Silversides)	Atlantic Silverside	*Menidia menidia*
	Inland Silverside	*Menidia beryllina*
Gasterosteidae (Sticklebacks)	Fourspine Stickleback	*Apeltes quadracus*
	Threespine Stickleback	*Gasterosteus aculeatus*

Table 11-2 (continued): Fish found at Wells NERR. Sources: Fish of the Wells National Estuarine Research Reserve (Checklist), 2002, Casco Bay 2002-4, NEC Project 2002-3, NOAA Project 2005-6
* These species have been found in Gulf of Maine nearshore habitats adjacent to Wells NERR estuaries.

Family	Common Name	Scientific Name
	Blackspotted Stickleback	*Gasterosteus wheatlandi*
	Ninespine Stickleback	*Pungitius pungitius*
Syngnathidae (Pipefishes)	Northern Pipefish	*Syngnathus fuscus*
Percichthyidae (Perches)	Striped Bass	*Morone saxatilis*
	White Perch	*Morone americana*
Pomatomidae (Bluefishes)	Bluefish	*Pomatomus saltatrix*
Chaetodontidae (Butterflyfishes)	Spotfin Butterflyfish	*Chaetodon ocellatus*
Labridae (Wrasses)	Cunner	*Tautogolabrus adspersus*
Mugilidae (Mullets)	Striped Mullet	*Mugil cephalus*
Sphyraenidae (Barracudas)	Northern Sennet	*Sphyraena borealis*
Stichaeidae (Pricklebacks)	Snake Blenny	*Lumpenus lumpretaeformis*
	Radiated Shanny	*Ulvaria subbifurcata*
Pholidae (Gunnels)	Rock Gunnel	*Pholis gunnellus*
Ammodytidae (Sand Lances)	Sand Lance	*Ammodytes americanus*
Scombridae (Mackerels)	Atlantic Mackerel	*Scomber scombrus*
Stromateidae (Butterfishes)	Butterfish	*Peprilus tricanthus*
Cottidae (Sculpins)	Grubby Sculpin	*Myoxocephalus aeneus*
	Longhorn Sculpin	*Myoxocephalus octodecimspinosus*
	Slimy Sculpin	*Cottus cognatus*
Cyclopteridae (Snailfishes)	Lumpfish	*Cyclopterus lumpus*
	Seasnail	*Liparis atlanticus*
Bothidae (Lefteye Flounders)	Windowpane	*Scopthalmus aquosus*
Pleuronectidae (Righteye Flounders)	Winter Flounder	*Pseudopleuronectes americanus*
	Witch Flounder	*Ictalurus nebulosus**
	American Plaice	*Hippoglossoides platessoides**
	Atlantic Halibut	*Hippoglossus hippoglossus**
	Yellowtail Flounder	*Limanda ferruginea**
	Smooth Flounder	*Liopsetta putnami*
Esocidae (Pikes)	Chain Pickerel	*Esox niger*
Cyprinidae (Minnows)	Golden Shiner	*Notemigonus crysoleucas*
	Creek Chub	*Semotilus atromaculatus*
Catostomidae (Suckers)	White Sucker	*Catostomus commersoni*
Centrarchidae (Sunfishes)	Pumpkinseed	*Lepomis gibbosus*
	Bluegill	*Lepomis macrochirus*
	Largemouth Bass	*Micropterus salmoides*
Ictaluridae (Bullhead Catfishes)	Brown Bullhead	*Ictalurus nebulosus*
Sphyraenidae (Barracudas)	Northern Barracuda	*Sphyraena borealis*
Triglidae (Sea Robins)	Northern Sea Robin	*Prionotus carolinus**
Anarhichadidae (Wolffishes)	Atlantic Wolffish	*Anarhichas lupus**
Hemitripteridae (Sea Ravens)	Sea Raven	*Hemitripterus americanus**
Lophiidae (Monkfishes)	Monkfish	*Lophius americanus**
Ophidiidae (Cusk eels)	Fawn Cusk-eel	*Lepophidium profundorum**
Scorpaenidae (Rockfishes)	Acadian Redfish	*Sebastes fasciatus**

Chapter 12

Birds

Charles Lubelczyk and Kathleen M. O'Brien

Southern Maine has a rich and diverse faunal community, largely due to the meeting and blending of two distinct ecosystems, the oak-pine ecosystems of the North Atlantic coast and the more northern softwood-dominated ecosystems to the north. Wells NERR lies within this unique transition zone. Particularly diverse in undeveloped habitats is the bird population that occurs along the coastal strip of southern Maine. Although the area has historically been under development pressure, areas such as Wells NERR serve as important sanctuaries both as breeding sites and as stopover habitat for migrating birds. The Wells Reserve is considered part of US Fish and Wildlife Bird Conservation Region (BCR) 30 (USFWS 2006). This region, extending from extreme southwestern Maine to Virginia, is over 9 million ha in size and includes coastal habitats as well as marine habitats out to the continental shelf (USFWS 2002). Bordering this region is BCR 14, which extends from southern Maine through maritime Atlantic Canada. Within this area, it is possible to see a wide variety of species that are conservation targets for both BCR 30 and BCR 14. These target species include the American black buck, piping plover and salt marsh sharptailed sparrow.

In this chapter, we will discuss the avian communities and their habitats present at Wells NERR. Although each habitat described might have particular indicator species, it is common for birds to travel through and utilize a variety of habitats during breeding, migration and wintering seasons, as food resources improve or decline during the year. Currently, over 250 species of birds have been observed on the Reserve, either through passive sighting or through intensive surveys. Management recommendations for avian species of concern are presented.

History of Studies at Wells NERR

Beginning in 1988, Wells NERR incorporated a bird banding program on the premises as part of its upland surveys. Although initially located in an outlying parcel known as the "Alheim Commons" in its first year, the program was moved to a central location on the Reserve, with 10 twelve-meter mist

Figure 12-1: US Fish and Wildlife Bird Conservation Regions 30. Source US Fish and Wildlife Service.

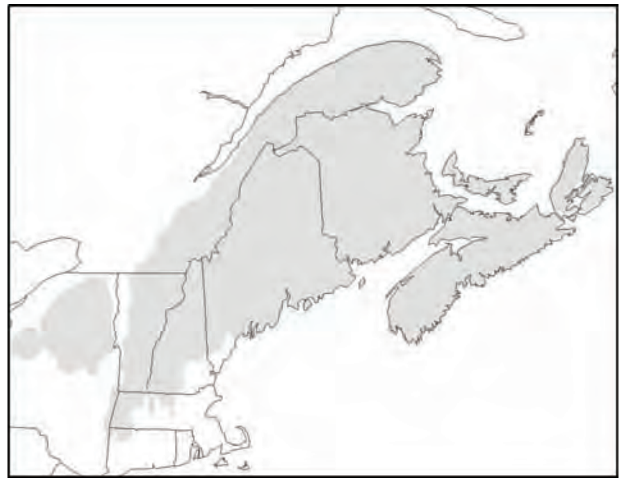


Figure 12-2: US Fish and Wildlife Bird Conservation Region 14. Source US Fish and Wildlife Service.

nets located in second-growth forest and successional field habitat. The mist-netting program, conducted by J. M. Ficker (USFWS Master Bander Permit #21419), surveys for breeding birds weekly from the last week of May through August. In 1990, this banding program became a site for the Monitoring Avian Productivity and Survivorship (MAPS) administered by the Institute for Bird Population Studies, headquartered in Point Reyes, California. A complement to this program was the addition of a banding program monitoring abundance of saw-whet owls (*Aegolius acadicus*) in 1994. This banding program, conducted from late September through November, bands owls migrating south along the coastal corridor. Wells NERR is also a site used by the Audubon Society for its annual Breeding Bird Survey conducted in June and the Christmas Bird Count.

Generally, standardized surveys for birds have focused on upland species at Wells NERR, despite its proximity to coastal waters. An informal survey of waterfowl and shorebirds was conducted by volunteers of the Reserve in the 1990's. These surveys began as a project investigating the feeding behavior of large wading birds (primarily great blue herons and snowy egrets), finding that the birds favored less developed areas with a high density of pools and channels (S. Walker, unpublished data, 1991). Annual monitoring of large wading birds continued during the summer months through 2001. Wading birds can be considered an indicator species for salt marsh ecosystem state, given that

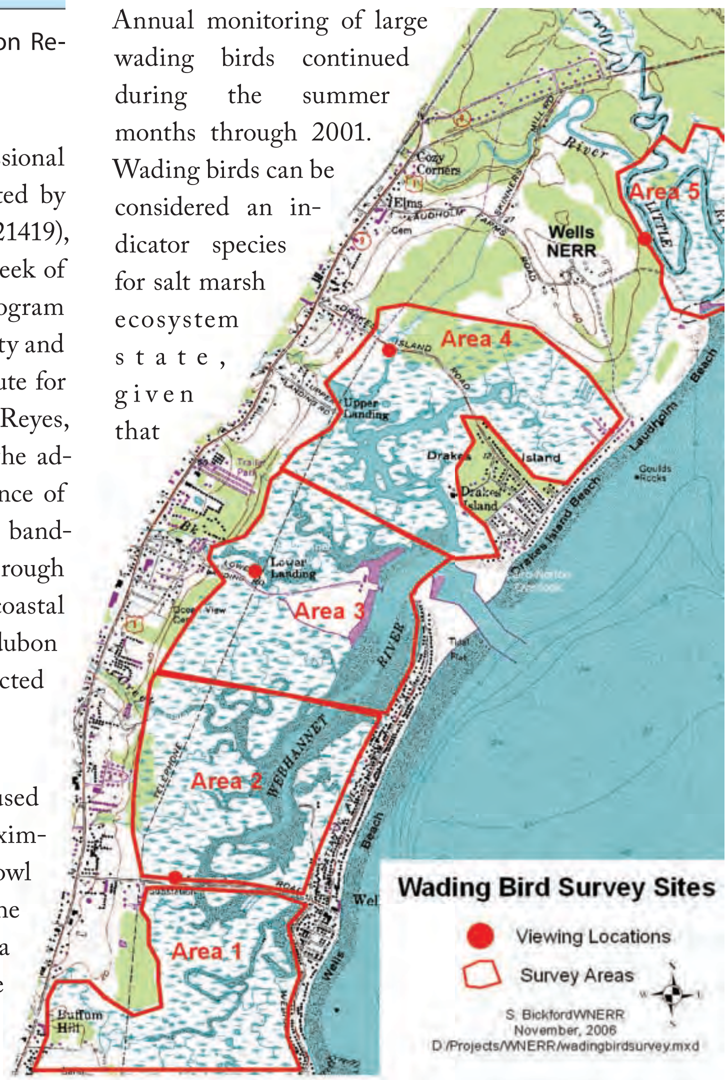


Figure 12-3: Map of Wading Bird Survey Sites. Areas 1, 2, 3 and 4 are on the Webhannet marsh, and Area 5 is on the Little River marsh.

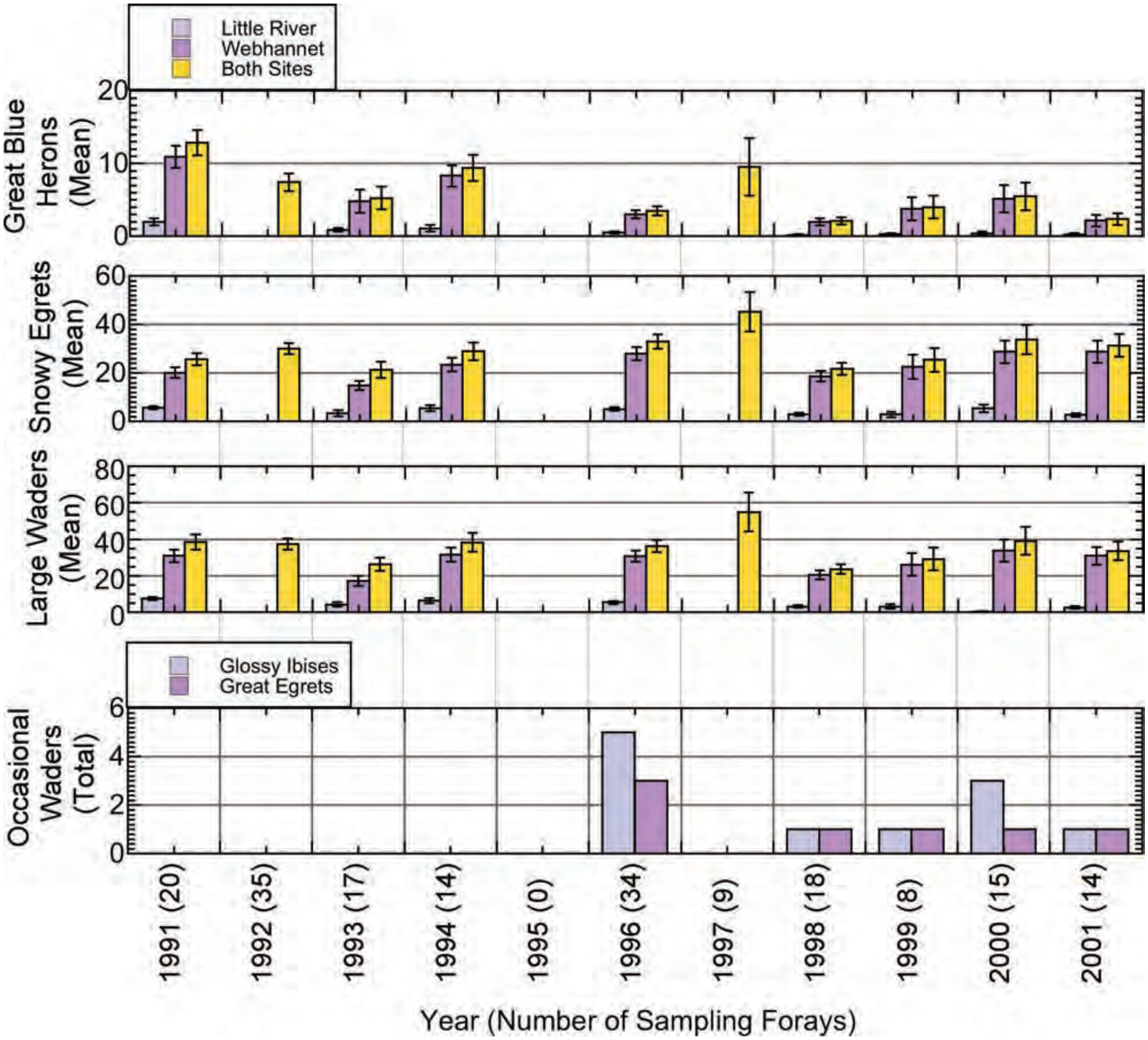


Figure 12-4: Means and standard errors of the number of large wading birds observed on the marshes of Wells NERR during daylight high tide. Note variation in vertical scale and absence of data for 1995. Number of surveys indicated in parentheses after year. Figure Hannah Wilhelm.

they are top predators in the marsh food web, based on the hypothesis that their populations are linked to prey abundance in Gulf of Maine coastal wetlands, as they are in the southeastern states. Large wading bird abundance is being used as one of the primary indicators of ecosystem status and change for the extensive and long-term effort to restore the Florida everglades and other South Florida wetlands (Williams and Melvin 2005). The rationale for using this group as an indicator is based on the linkage between hydrology, prey abundance (fish and crustaceans) and bird population size (Ogden 1994, Gawlik 2002, Cook and Call 2006). Although there are many more wader species using coastal wetlands in the southeast than in the Gulf of Maine, snowy egrets and great blue herons show both numerical and population responses to increased prey abundance from a number of studies in Florida and one in Louisiana (Fleury and Sherry 1995).

From June to September volunteers and interns counted all large wading birds on the high marsh (including high marsh pools) of the Webhannet and Little River estuaries, working from several observing stations (Fig. 12-3). Birds were counted using a spotting scope and

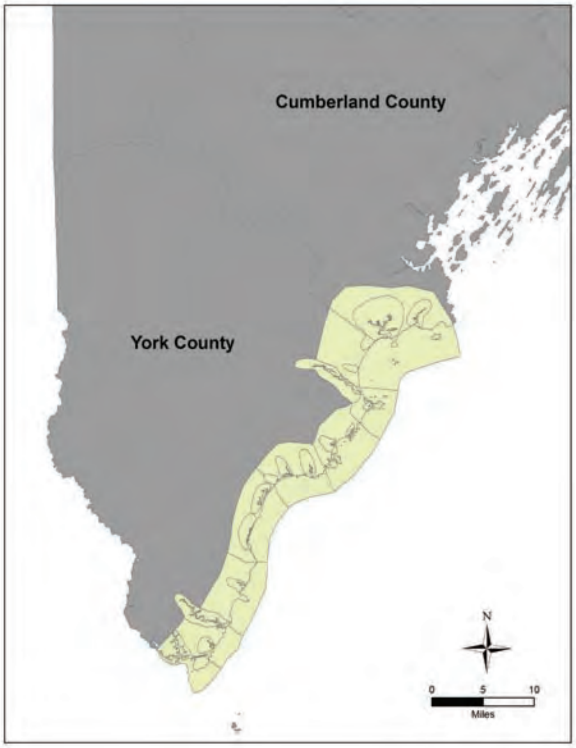


Figure 12-5: Mid-Winter Waterfowl Survey Unit 8 encompasses the coastline of Wells NERR. Data U.S. Fish and Wildlife.

A nest, most likely belonging to a willet, photographed in the Wheeler marsh. Photo Wells NERR.

high-powered binoculars, and the approximate location of each individual was marked on a map. Surveys were conducted at high tide, when all waders are visible on the marsh surface.

Ten years of wading bird surveys reveal a potential downward trend in the number of great blue herons observed but a steady population of wading birds overall (Fig. 12-40). During the survey period, the mean number and standard error of great blue herons observed on the Reserve's estuaries was $\bar{x} = 6.1 \pm 1$ SE while that for snowy egrets was $\bar{x} = 29 \pm 2$ SE.

The administrative boundary of the Reserve includes lands owned and managed by the United States Fish and Wildlife Service Rachel Carson National Wildlife Refuge (USFWS-RCNWR). For this chapter we will draw upon RCNWR datasets and studies. A limited number of aerial waterfowl surveys have been conducted within the Reserve boundaries from 1998-2002. The Reserve also falls within Unit 8, for the annual mid-winter waterfowl survey (Fig. 12-5). RCNWR has conducted surveys and studies of the sharp-tailed sparrows (*Ammodramus caudacutus* and *A. nelsonii*) and other salt marsh birds breeding within the Reserve, and has cooperatively monitored the federally threatened, state endangered piping plover and the state endangered least tern which both nest upon Laudholm Beach.

Habitats

Forest

According to Widoff (1985), forest habitat on Wells NERR can be characterized into four categories - red maple swamps, oak-pine forests, pine barrens, and mixed second-growth forest. Red maple (*Acer rubrum*) swamp habitat is common on the Reserve, frequently found adjacent to salt marshes in the lowland areas. Red maple, while the dominant canopy tree, can be found mixed with black cherry (*Prunus serotina*), red spruce (*Picea rubens*) and white birch (*Betula papyrifera*), and, occasionally, yellow birch (*Betula allegheniensis*). In some areas, a substantial shrub layer, composed of native blueberries (*Vaccinuim* spp.) alders (*Alnus rugosa*) and winterberry holly (*Ilex verticillata*) exists. Just as often, the shrub layer might be formed on non-natives, particularly Japanese barberry (*Berberis thunbergii*) and European buckthorn (*Rhamnus cathartica*). Common passerine birds found in these areas are shrub-nesting or ground-foraging songbirds including common yellowthroats (*Geothlypis trichas*), chestnut-sided warblers (*Dendroica pensylvanica*), black-throated green warbler (*Dendroica virens*), American redstarts

(*Setophaga ruticilla*), veeries (*Catharus fuscecens*), northern waterthrush (*Seirus noveboracensis*), eastern towhees (*Pipilo erythrophthalmus*), catbirds (*Dumetella carolinensis*), alder and willow flycatchers (*Empidonax* spp.). The proximity to marshes also allows for the occasional presence of harriers (*Circus cyaneus*) while adjacent fields might attract red-tailed hawks (*Buteo jamaicensis*) into these forests. Higher canopy species such as the ubiquitous black-capped chickadee (*Poecile atricapillus*), the uncommon blackburnian warbler (*Dendroica fusca*), and black-billed cuckoo (*Coccyzus erythroptalmus*) may also occur. In the forested wetlands American woodcock (*Scolopax minor*) utilize this habitat to forage for earthworms.

Pine forests may be classified into two distinct types on the Reserve, pine plantations composed of either eastern white pine (*Pinus strobus*) or red pine (*Pinus resinosa*) in upland areas. Little or no shrub layer exists in these forests. Along the immediate coastal portions of the Reserve, a band of maritime forest characterized by pitch pine (*Pinus rigida*) and scrub oak (*Quercus ilicifolia*) is present. Common shrub layer vegetation in this forest includes bayberry (*Myrica pennsylvanica*), poison ivy (*Toxicodendron radicans*) and roses (*Rosa* spp.). Found in these forests are the black-capped chickadee, tufted titmice (*Baeolophus bicolor*), white-breasted and red-breasted nuthatch (*Sitta* spp.), brown creeper (*Certhia americana*), American crow (*Corvus brachyrhynchos*), and blue jays (*Cyanocitta cristata*). The tallest pines can serve as roosts for raptors or other predators such as crows. Avian predators at Wells NERR in this habitat include the red-tailed hawk, broadwing hawk (*B. platypterus*), barred owl (*Stryx varia*), and northern saw-whet owl. Pine plantations also

Fresh holes mark the presence of a pileated woodpecker. Photo Scott Richardson.

provide a seasonal refugium for wild turkeys (*Meleagris gallopavo*), who congregate near these forests in winter for thermal protection and for the benefit of reduced snow pack.

Oak-pine forests are dominated by eastern white pine and red oak (*Quercus rubra*). An intermittent shrub layer might contain high-bush blueberry (*Vaccinium corymbosum*), Japanese barberry, or black huckleberry (*Gaylussacia baccata*). This area is noted for its high canopy, abundant mast crop from acorns, and the resulting snags that appear as mature trees die. Although many types of trees are utilized by woodpeckers on the Reserve, this habitat produced suitably large cavities to accommodate the largest species on the Reserve, the pileated woodpecker (*Dryocopus pileatus*). Other woodpeckers commonly seen in this habitat and other forest types include downy woodpeckers (*Picoides pubescens*), hairy woodpeckers (*Picoides villosus*), yellow-bellied sapsuckers (*Sphyrapicus varius*), and northern flickers (*Colaptes auratus*). Cavities begun by woodpeckers might later be occupied by saw-whet owls, as the predators move into the area. Figure 12-6 illustrates numbers of saw-whet owls mist-netted in oak-pine forests at the Reserve over an eleven-year span.

Second-growth forests on the Reserve are usually a combination of the three other types of forest listed above. Canopy species frequently include red maple, red oak, and eastern white pine but may also have quaking aspen (*Populus tremuloides*) in younger portions of the forest. Apple trees (*Malus* spp.), remnants of orchards overtaken by the successional process, also appear intermittently as a mid-canopy species. The shrub layer in this forest can be extremely dense at some points, consisting primarily of three non-native species: barberry (Common and Japanese), honeysuckle (*Lonicera* spp.), and Asiatic bittersweet (*Celastrus orbiculatus*). The songbird community in this habitat is diverse, with many of the species found in other forests types also using these woods. Many woodpeckers, thrushes, sparrows, and warblers might be found using the shrub layer as cover or forage. Of particular interest is the presence of the blue-winged warbler (*Vermivora pinus*), black and white warbler (*Mniotilta varia*), yellow-rumped warbler (*Dendroica coronata*), Canada warbler (*Wilsonia canadensis*), song sparrow (*Melospiza melodia*), Lincoln's sparrow (*M. lincolnii*), scarlet tanager (*Piranga olivacea*), eastern towhee, wood thrush (*Hylocichla muste-*

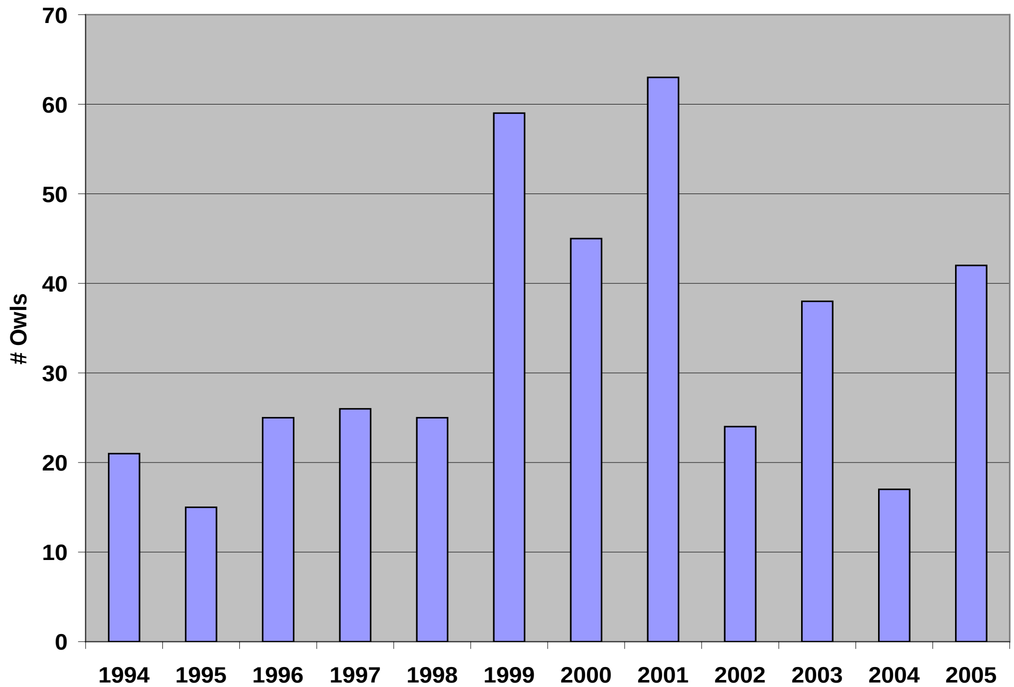
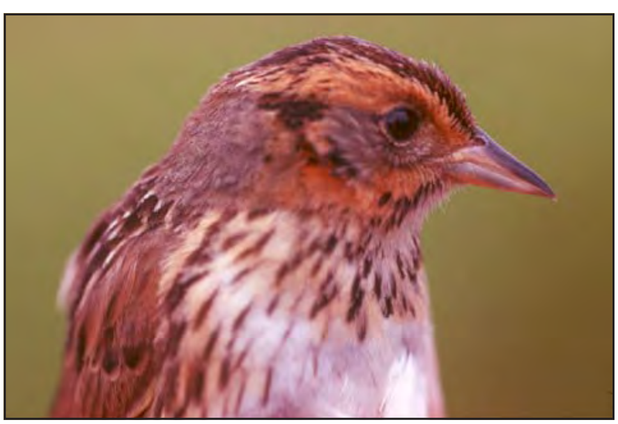


Figure 12-6: Numbers of northern saw-whet owls banded on Wells NERR from Sept-Nov. 1994-1995. Courtesy of June M. Ficker.

lina), hermit thrush (*Catharus guttatus*), and rose-breasted grosbeak (*Pheucticus ludovicianus*). Remnant apple and cherry trees also provide forage for ruby-throated hummingbird (*Archilochus colubris*), the only hummingbird found in New England. Woodcock, turkey (*Melegarus galloparo*), and pheasant (*Phasianus colchicus*) nests might also be found here, if in the vicinity of field habitat. The abundant small mammal community provides forage for hawks and owls, particularly barred, saw-whet, and great horned owls (*Bubo virginianus*). Cooper's hawks (*Accipiter cooperii*) and sharp-shinned hawks (*Accipiter striatus*) may also be found hunting for passerines in these forests.



Saltmarsh sharp-tailed sparrow. Photo Greg Shriver

Fields

Managed fields compose an important part of the upland community at Wells NERR. For some birds, mown or managed fields are absolutely critical. The acknowledged loss of this habitat in the northeast through development or succession makes it critical to maintain fields in the future. Noticeably, the most prominent birds that use mown fields at Wells NERR are bobolinks (*Dolichonyx oryzivorus*). Several areas adjacent to the developed portions of the Reserve serve as breeding and foraging habitat for this species, regionally in decline (Bollinger and Gavin 1992). Other birds that are found in this habitat include the eastern meadowlark (Sturnella magna), field sparrows (*Spizella pusilla*), Eastern kingbird (*Tyrannus tyrannus*), and American woodcock, which are also declining in the region (USFWS, 2006), in addition to barn swallows (*Hirundo rustica*), tree swallows (*Spizella arborea*), wild turkey, and bluebirds (*Sialla sialis*), whose abundance is apparently increasing due to placement and maintenance of nest boxes. Although the above mentioned species utilize mown fields during the breeding

A single snowy egret feeding in a marsh pool. Photo B.A. King.

season, Wells NERR also has birds that use this habitat in their wintering grounds. Three conspicuous winter visitors using the low grasses are the snow bunting (*Plectrophenax nivalis*), dark-eyed junco (*Junco hyernalis*), and rarer Lapland longspur (*Calcarius lapponicus*). Two other, less desirous, species can be found in mown fields year round at the Reserve, European starlings (*Sturnus vulgaris*), and house sparrows (*Passer domesticus*).

Shrublands and Thicket

Successional fields abound at Wells NERR, of varying age. Dominated primarily by non-native vegetation such as barberry, honeysuckle and bittersweet, but containing remnant apple, cherry, alder, rose, bayberry, and blueberr as well, this habitat is critical for many species of birds that use shrubs for forage and cover. Nine species listed as highest or high conservation priority within BCR 30 are shrubland-dependant species. At the Wells Reserve, eight of these species have been documented (American woodcock, prairie warbler [*Dendroica discolor*], blue-winged warbler, brown thrasher [*Toxostoma rufum*], Eastern towhee, field sparrow [*Spizella pusilla*], whip-poor-will [*Caprimulgus vociferus*] and willow flycatcher [*Empidonax traillii*]) (USFWS 2006). Many species found here are in decline across the northeast because of habitat loss from succession and development pressure. In fact, many sparrows, including song sparrows, field sparrows, and white throated sparrows are found in this habitat. Species that are abundant in successional habitats include brown thrashers, catbirds, common yellowthroat, and mockingbirds (*Mimus polyglottos*) as well as cedar waxwings (*Bombycilla cedrorum*) that take advantage of the many fruiting shrubs in the breeding season. The presence of barberry give pheasants and turkey a soft mast crop during the fall season and might provide shelter and potential nest sites for passerines (Schmidt and Whelan 1999). Barberry is thought to be a low quality food source for wildlife, although its berries do persist into winter when other foods may be unavailable (Stiles 1980).

Along with successional habitats, maritime shrublands which grow along the buffer of the upland habitats and the salt marsh consist of many species with high wildlife food value. Bayberry, roses, viburnums and other fruiting shrubs offer habitats critical to migratory landbirds.

Freshwater Marshes

Freshwater marsh habitat is limited within the Reserve. There are several small pockets of freshwater marsh either bordering salt marsh habitat or where tidal flow is restricted. Virginia rail (*Ramis limicola*), green heron (*Butorides virescens*) and the occasional American bittern (*Botaurus lentiginosus*) can occur in these areas during the breeding season and during migration.

Tidal Marshes

Within the boundaries of the Wells NERR, tidal marsh, estuary and tidal river habitats are common. The Wells and Ogunquit marsh complexes (Moody, Wells, Little River and Mousam River) together comprise the second largest salt marsh complex within the State of Maine and are designated as a Focus Area of State-wide Significance due to exemplary habitat within the area. This marsh complex is about 2,250 acres in size, although the some parcels remain in private ownership, and the Mousam River portion lies outside of the Reserve boundary. In addition to the salt marsh habitats, the Reserve includes seven tidal mainstem channels and tributaries, providing excellent habitat for waterfowl, waterbirds, shorebirds, raptors and passerines.

The area's prime importance to waterfowl is as a migratory and wintering habitat, although a small number of mallards (*Anas platyrhynchos*), black ducks (*Anas rubripes*), common eider (*Somateria mollissima*) and resident geese utilize the marshes and estuaries during the breeding season. However, during migration it is not uncommon for hundreds of black ducks to be observed utilizing the

A pair of piping plovers. Photo Ted Cunningham.

salt marsh habitats. For the winter months, black ducks are joined by common loons (*Gavia immer*), common goldeneye (*Bucephala clangula*), buffleheads (*Bucephala albeola*), long-tailed ducks (*Clangula hyemalis*), common eiders, mallard, North Atlantic Canada geese (*Branta canadensis*) and red-breasted mergansers (*Mergus serrator*). American black ducks are a species of the highest conservation priority within BCR 30.

The tidal habitats also offer high quality habitats for shorebird species. Several priority shorebirds regularly occur within the salt marsh and mudflat habitats within the Reserve, including sanderling (*Calidris alba*), greater yellowlegs (*Tringa melanoleuca*), semi-palmated sandpipers (*Calidris pusilla*), short-billed dowitchers (*Limnodromus griseus*), among others. Willet (*Catoptrophorus semipalmatus*), a species of high conservation priority, is a common breeder within these marsh complexes as well.

At this time, monitoring of the entire marsh system is not possible; however, some selected areas are surveyed during migration for shorebird use by Rachel Carson National Wildlife Refuge staff. The data for the Oxcart Lane area (Fig. 12-7) is submitted for inclusion within the International Shorebird Survey (ISS) database.

Tidal marshes and rivers provide feeding areas for a diversity of marsh and wading birds. Green heron, great blue heron, snowy egrets, great egrets, glossy ibis, and little blue heron nest on Maine's offshore islands, but feed within the Reserve's salt marsh habitats.

Salt marsh and Nelson sharp-tailed sparrows nest in the tidal marshes of the Reserve, and in certain areas occur in great concentrations. Salt marsh sharp-tailed sparrows are obligate salt marsh species, are range restricted, with breeding occurring only from the Weskeag River in Maine to Virginia (Hodgman et al. 2002, Greenlaw and Rising, 1994). They are of great conservation concern. Nelson sharp-tailed sparrows nest in coastal salt marshes from Parker River National Wildlife Refuge Massachusetts, northwards into Canada (Hodgman *et al*. 2002). In the midwest, Nelsons will also nest in freshwater marshes. The salt marsh sharp-tailed sparrow (pictured) is considered globally vulnerable to extinction according to the IUCN Red List criteria, and is listed as one of the top conservation priorities for BCR 30. Nelsons are also of conservation concern, but their populations are believed to be more secure. Rachel Carson National Wildlife Refuge has been surveying sharp-tailed sparrows for the past 8 years and will be completing a trend analysis in 2007.

Of particular interest, the Reserve falls within the area where these two species meet, overlap and hybridize

	Piping Plover Pairs and Productivity			Least Terns Pairs and Productivity		
Year	Laudholm	Crescent Surf	Entire State	Laudholm	Crescent Surf	Entire State
1997	1 (2)	4 (13)	47 (93)	0	20 (1)	50 (11)
1998	2 (3)	3 (6)	60 (88)	1 (2)	20 (7)	86 (12)
1999	4 (11)	4 (4)	56 (91)	20 (20)	40 (45)	62 (67)
2000	6 (14)	3 (6)	50 (80)	37 (17)	85 (62)	126 (81)
2001	4 (14)	5 (14)	55 (109)	15 (#)	102 (57)	120 (63)
2002	5 (15)	5 (6)	66 (91)	12 (#)	81 (145)	121 (155)
2003	6 (10)	8 (0)	61 (78)	20 (0)	57 (8)	156 (66)
2004	5 (3)	3 (4)	55 (80)	1 (0)	50 (3)	146 (69)
2005	1 (1)	6 (5)	49 (27)	4 (1)	52 (7)	114 (20)
2006	0	5 (4)	40 (54)	0	30 (10)	134 (26)

Table 12-1: Piping Plover and Least Tern numbers and productivity at Wells NERR and in the state of Maine. Pairs (Fledglings), # Fledglings counted within Crescent Surf total. Data from Jones *et al*. (2005).

A least tern in flight. Photo Scott Richardson.

(Shriver *et al*. 2005, Hodgman *et al*. 2002). Management issues identified for sharp-tailed sparrows include sea level rise, mercury contamination, disturbance, habitat degradation and invasive plants.

Sandy Beach and Dune

Laudholm Beach is one of the last remaining undeveloped stretches of primary dune and sandy beach within Southern Maine. It is approximately 1.2 km long and is an important breeding area for the federally threatened, state endangered, piping plover and the state endangered least tern. The area has been designated by the state of Maine as essential habitat for least tern and piping plover. Essential habitat receives regulatory protection under the Maine Endangered Species Act which requires that no state agency or municipal government shall permit, license, fund or carry out projects that would significantly alter the habitat or violate protection guidelines adopted for the habitat (12 MRSA Part 13, Subchapter 3 - Endangered Species).

Piping plover (*Charadrius melodus*) populations have been monitored within the state of Maine since 1981. The first nesting pair of plovers was recorded for Laudholm Beach in 1991 and the beach has had piping plovers nesting on it from 1991-2005 (Table 12-1, Jones *et al* 2005). In 2006, there was no nesting activity documented, although plovers did use the area for feeding and migration. Crescent Surf Beach, which lies directly east of Laudholm Beach, (across the Little River inlet) and is connected to Laudholm Beach on spring low tides, but is not within the Reserve boundary, had 5 pairs of nesting

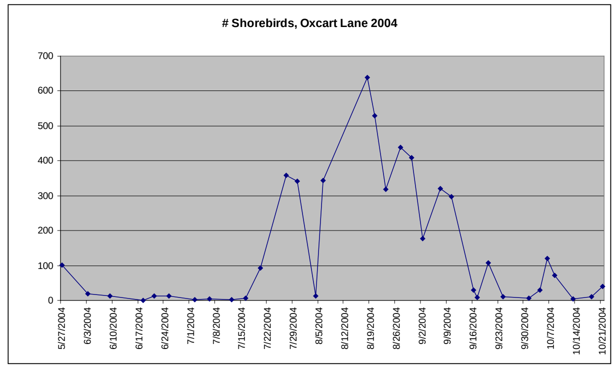


Figure 12-7: Data from the Oxcart Lane surveys conducted in 2004 (K. O'Brien unpublished data).

plovers which fed in the mudflats of Laudholm Beach. The two areas together make up an important area for plovers within the State.

Least terns (*Sterna antillarum*) are listed as state-endangered and are a species of high conservation priority for USFWS and have been monitored within the state since 1977. Least terns have a dynamic nesting strategy; colony shifts are common responses to changes in habitat or disturbance from predators or people. Least terns reach the most northern portion of their range here in southern Maine. Gathering accurate population estimates for the state is difficult due to their dynamic nesting habits; however, the population estimate has ranged from 50 pairs to 156 pairs within the state over the past 10 years. Laudholm has provided breeding habitat for 1 – 37 pairs within the same time frame. However, the Laudholm and Crescent Surf beaches function biologically as one

Looking for birds on the marsh. Photo Scott Richardson.

Determining the age of a saw whet owl by its wing feathers. This is a second-year bird. Photo June Ficker.

colony, and the two sites together generally host the bulk of least terns nesting within the State.

In recent years, predators and beach erosion have depressed the nesting activity for plovers and terns at Laudholm Beach. In 2006, there were no nesting plovers or terns present and the habitat available to them was of exceedingly low quality. Beach erosion has left only a small band of sandy habitat for nesting, which is not attractive to the birds. Predators further depressed productivity at the adjoining Crescent Surf Beach. The Piping Plover Recovery Plan calls for a minimum productivity of 1.5 fledglings per a pair to ensure plover population growth. For 7 out of the past 10 years Laudholm has met or exceeded those productivity measures. However, recent years have fallen well below that standard.

The area is also an important staging area for common and roseate terns before they begin their fall migration south. Roseate terns are federally and state endangered. Hundreds of common terns and up to twenty roseate terns have used the area to stage for fall migration. In addition to a late summer/fall staging area for terns, the area is also an important roost and feeding area for migratory shorebirds. In 2006, hundreds of semipalmated plovers, semipalmated sandpipers, peeps, and sanderlings were documented using Laudholm Beach as a roost area.

Coastal Waters

Direct coastline within the Reserve's boundary is somewhat limited, with the exception of Laudholm Beach. However the protected salt marshes and estuaries within the boundaries directly benefit the bird resources utilizing coastal waters. During the fall and during the winter months hundreds of waterbirds use coastal waters for feeding and rafting.

As part of waterfowl monitoring the state of Maine and USFWS conduct a winter waterfowl survey in early January (Table 12-2). These surveys serve as an index for the population and are a good indication of the wintering waterfowl that inhabit the coastal waters of

	Mallard	BlackDuck	Common Goldeneye	Bufflehead	Long-tailed Duck	All Scoters	Common Eiders	Mergansers	Canada Geese
2005	283	2015	115	132	95	669	3427	65	394
2004*	839	2720	310	294	161	34	2353	91	760
2003	514	1974	174	241	148	959	2908	104	392
2002	880	2665	221	224	341	116	6626	958	529
2001	419	710	71	103	224	510	4477	126	567
2000	221	1014	117	77	301	850	5129	434	402

** In 2004, the mid-winter waterfowl survey had insufficient funds, and was cancelled. Some dollars were found to do a minimal survey of important black duck habitats, so much of the coast and marsh was flown.*

Table 12-2: Selected Species Documented in the Mid-Winter Waterfowl Survey for Unit 8.

the Reserve. Portions of the Reserve lie within Unit 8 and this unit is further broken down into subunits. In addition to waterfowl, the coastal waters are home to wintering common and red-throated loon (*Gavia stellata*). Total waterfowl observed in 2005 was 7,857. Midwinter waterfowl counts vary greatly depending on weather and ice conditions. Numbers are useful for interpretation over long time intervals.

Research Overview

Role of Birds in Lyme Disease Ecology

As part of an effort to better understand the complex ecology of Lyme disease and its vector tick, *Ixodes scapularis*, information on tick burdens and infection rates were collected beginning in 1989 from breeding passerine birds. Collected in 12-meter mist nests, each bird is individually numbered, sexed, aged, and reproductive status recorded. Ticks are removed and identified to species at the Maine Medical Center Research Institute in South Portland, Maine. Suitable specimens are examined by darkfield microscopy for the presence of the spirochete that causes Lyme disease, *Borrelia burgdorferi*. Rand *et al*. (1998) found that many species of ground nesting and shrub foraging birds may host ticks and some, such as common yellowthroats and veeries, may act as reservoirs for the bacteria in nature while other species such as catbirds, are inefficient reservoirs of *B. burgdorferi*.

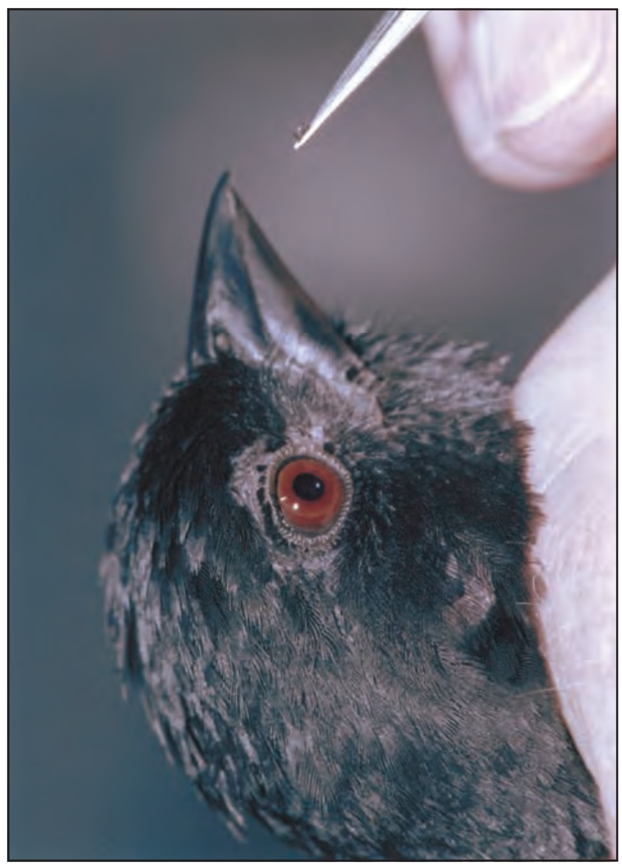
Migratory Studies of Owls

Collaborating with Dr. Keith Hobson of the Prairie and Northern Wildlife Research Center, Environment Canada in Saskatoon, SK Canada, bird banders at the Reserve have collected samples for isotope analysis on feathers plucked from northern saw-whet owls. Owls banded during the fall southward migration or on wintering grounds can be traced back to their previous summer grounds using stable isotope analysis of feather protein. By analyzing feathers grown during the previous year, researchers can study population movement patterns.

Human Influences

Deer

The abundance of white-tailed deer (*Odocoileus virginianus*) in south coastal Maine has been a concern of both natural resource managers and public health professionals. In addition to its role in the ecology of Lyme disease, deer overabundance has been linked to songbird declines



Removal of a tick from a male, second-year returning rufous-sided towhee, originally banded at Wells NERR in 2005. Photo June Ficker.

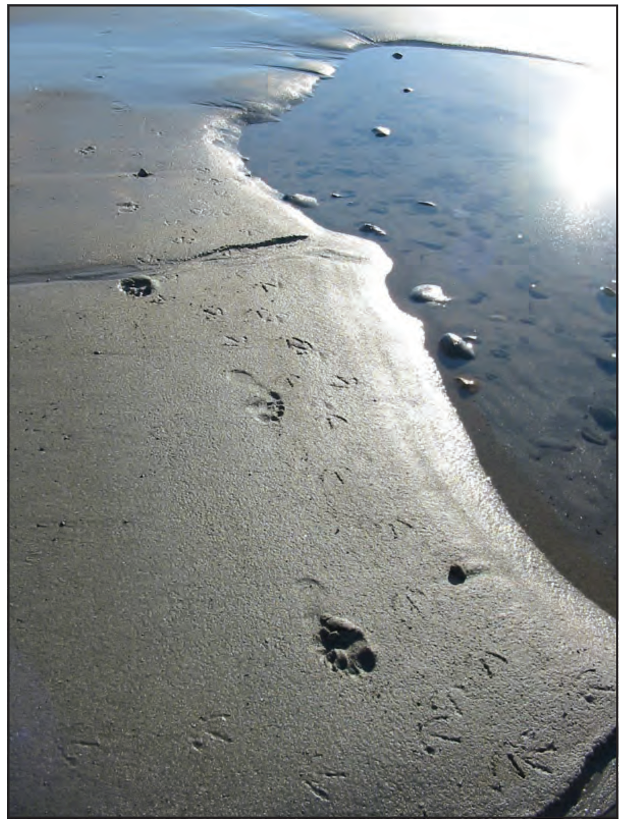
in northeastern forests (DeCalesta 1994). It has been estimated that deer densities over 7.9 km^{-2} begin to show adverse effects on the vegetation community and impact bird populations, primarily those species utilizing the ground and lower shrub layers. The most recent estimate of deer density at Wells NERR placed deer densities over 40 km^{-2}. Until 2002, deer hunting was prohibited on Wells NERR because of its status as a state game sanctuary, a provision that dated to the 1930's.

Invasives

The former agricultural use of the property that was to become Wells NERR allowed for the colonization of many of the exotics that plague the Reserve today. Many, including barberries, honeysuckles, and bittersweet, were imported in the 1800's from Europe or Asia. Finding little competition or predators, these plants thrived.

Habitat Loss

In addition to being the most ecologically diverse region of Maine, south coastal Maine also contains the highest human population. Coastal parcels have increased in dramatically in economic value, making land conservation much more difficult as development pressures increase.

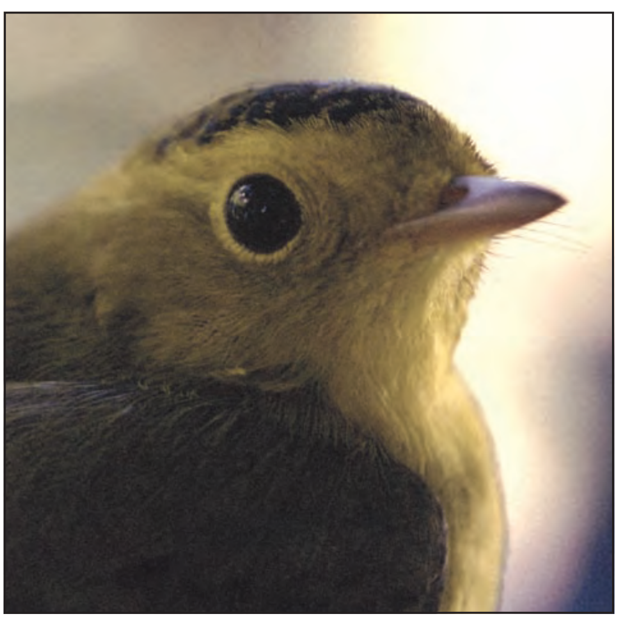


Human and avian prints side by side on Laudholm Beach. Photo by Susan Bickford.

Research Needs

Effects of Landscape Change

Efforts to control invasives and exotics, while a priority for upland management at the Reserve, have not been associated with the abundance of bird populations. Previous research has demonstrated that nesting success increases and predation decreases in association with exotic vegetation (Schmidt *et al*. 2005) or that presence of exotics decreases nesting success of songbirds (Borgmann and Rodewald 2004). Regardless of effects on songbirds, upland game birds such as turkey and pheasant benefit from the presence of soft mast crops produced by barberries in the fall (Stiles 1980).



A male Wilson's warbler. Photo June Ficker.

Mercury within Salt Marsh Passerines

Exceedingly high levels of mercury have been detected in the blood of salt marsh sharp-tailed sparrows nesting within the Reserve salt marshes (Shriver *et al*. 2006, Lane and Evers 2005). Additional research is necessary to determine the pathways of mercury for this species

Obtaining a cloacal swab from a veery. Photo June Ficker.

and if mercury impacts productivity or survival of the species.

Reducing Predation on Piping Plovers and Terns

Predation of the nests and chicks of plovers and terns has limited the ability of plovers nesting within the Reserve to meet recovery plan productivity criteria. Identification of predators responsible for nest and chick loss and determination of the best course of management action is a complex problem. Suites of predators appear to change on an annual basis, although some like crow are documented repeat offenders at the adjoining Crescent Surf Beach.

Beach Processes

In recent years Laudholm Beach has experienced serious beach erosion. The exact cause of that erosion is unclear. However, there have been changes in sea walls within the immediate area which could have resulted in changes in sand transport. In 2005, Nor'easters, which generally are winter storms, hit the beaches in the spring, further reducing the sandy habitat which was available for nesting plovers and terns. It is difficult to say if the changes at Laudholm Beach are part of a natural cycle, or influenced by human actions. Currently, much of the sand at Laudholm has been washed away and the beach has a more cobbled, or armored, appearance.

Management Recommendations

- ◊ Keep fields open for meadowlarks and boblinks. Mow fields after August 1, at a minimum every three years. Consider the use of mowing with periodic prescribed fires to encourage native grasses.
- ◊ Establish shrubland management units to benefit the suite of declining shrubland dependant birds which breed within the Northeast. Regenerate alder thickets and manage for native shrublands to benefit woodcock and other thicket dwelling birds.
- ◊ Continue to aggressively reduce the deer population through the use of hunting to enable natural forest regeneration processes and to assist shrub and ground nesting birds.
- ◊ Consider maintaining old apple orchards by releasing apple trees to benefit wildlife.
- ◊ Promote salt marsh health and when necessary, restore salt marshes by removing tidal restrictions and invasive plants; providing adequate buffers from upland land uses and runoff, and monitoring water quality.
- ◊ Reduce disturbance to nesting plovers and terns from people and dogs by working with state game wardens, ensuring signage is adequate and appropriate, and continuing to cooperatively manage the plover and tern population at Laudholm Beach with the assistance of Rachel Carson NWR.

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Table 12-3: Birds found at Wells NERR.

Family	Common Name	Scientific Name
Gaviidae (Loons)	Red-throated Loon	*Gavia stellata*
	Common Loon	*Gavia immer*
Podicipedidae (Grebes)	Horned Grebe	*Podiceps auritus*
	Red-necked Grebe	*Podiceps grisegna*
Sulidae (Boobies and Gannets)	Northern Gannet	*Morus bassanus*
Phalacrocoracidae (Cormorants)	Double-crested Cormorant	*Phalacrocorax auritus*
	Great Cormorant	*Phalacrocorax carbo*
Ardeidae (Herons, Egrets, and Bitterns)	American Bittern	*Botaurus lentiginosus*
	Great Blue Heron	*Ardea herodias*
	Great Egret	*Ardea alba*
	Snowy Egret	*Egretta thula*
	Little Blue Heron	*Egretta caerulea*
	Tricolored Heron	*Egretta tricolor*
	Green Heron	*Butorides virescens*
	Black-crowned Night-Heron	*Nycticorax nycticorax*
Threskiornithidae (Ibises and Spoonbills)	Glossy Ibis	*Plegadis falcinellus*
Cathartidae (New World Vultures)	Turkey Vulture	*Cathartes aura*
Anatidae (Ducks, Geese, and Swans)	Snow Goose	*Branta caerulescens*
	Canada Goose	*Branta canadensis*
	Brant	*Branta bernicla*
	Mute Swan	*Cygnus olor*
	Wood Duck	*Aix sponsa*
	Gadwall	*Anas strepera*
	American Wigeon	*Anas americanus*
	American Black Duck	*Anas rubripes*
	Mallard	*Anas platyrhynchos*
	Blue-winged Teal	*Anas discors*
	Northern Shoveler	*Anas clypeata*
	Northern Pintail	*Anas acuta*
	Green-winged Teal	*Anas crecca*
	Canvasback	*Aythya valisineria*
	Common Eider	*Somateria mollissima*
	Surf Scoter	*Melanitta perspicillata*
	White-winged Scoter	*Melanitta deglandi*
	Black Scoter	*Melanitta nigra*
	Long-tailed Duck	*Clangula hyemalis*
	Bufflehead	*Bucephala albeola*
	Common Goldeneye	*Bucephala clangula*
	Barrow's Goldeneye	*Bucephala islandica*
	Hooded Merganser	*Lophodytes cucullataus*
	Red-breasted Merganser	*Mergus serrator*
Accipitridae (Hawks, Eagles)	Osprey	*Pandion haliaetus*
	Bald Eagle	*Haliaeetus leucocoephalus*
	Northern Harrier	*Circus cyaneus*
	Sharp-shinned Hawk	*Accipiter striatus*
	Cooper's Hawk	*Acipiter cooperii*
	Northern Goshawk	*Acipiter gentilis*
	Broad-winged Hawk	*Buteo platypterus*
	Red-tailed Hawk	*Buteo jamiaicensis*
	Rough-legged Hawk	*Buteo lagopus*
	Golden Eagle	*Aquila chrysaetos*
Falconidae (Falcons and Caracaras)	American Kestrel	*Falco sparverius*
	Merlin	*Falco columbarius*
	Peregrine Falcon	*Falco peregrinus*
Phasianidae (Grouse, Turkey, Pheasants)	Ring-necked Pheasant	*Phasianus colchius*
	Ruffed Grouse	*Bonasa umbellus*
	Wild Turkey	*Meleagris gallopavo*

Table 12-3 (continued): Birds found at Wells NERR.

Family	Common Name	Scientific Name
Charadriidae (Plovers and Lapwings)	Black-bellied Plover	*Pluvvialis squatarola*
	American Golden-Plover	*Pluvialis dominica*
	Wilson's Plover	*Charadrius wilsonia*
	Semipalmated Plover	*Charadrius semipalmatus*
	Piping Plover	*Charadrius melodus*
	Killdeer	*Charadrius vociferus*
Scolopacidae (Sandpipers and Phalaropes)	American Avocet	*Recruvirostra americana*
	Greater Yellowlegs	*Tringa melanoleuca*
	Lesser Yellowlegs	*Tringa flavipes*
	Solitary Sandpiper	*Tringa solitaria*
	Willet	*Catoptorophorus semialmatrus*
	Spotted Sandpiper	*Actitis macularia*
	Upland Sandpiper	*Bartramia longicauda*
	Whimbrel	*Numenius phaeopus*
	Hudsonian Godwit	*Limosa haemastica*
	Ruddy Turnstone	*Arenaria interpres*
	Sanderling	*Calidris alba*
	Semipalmated Sandpiper	*Calidris pusilla*
	Western Sandpiper	*Calidris mauri*
	Least Sandpiper	*Calidris minutilla*
	White-rumped Sandpiper	*Calidris fuscicollis*
	Pectoral Sandpiper	*Calidris melanotos*
	Purple Sandpiper	*Calidris maritima*
	Dunlin	*Calidris alpina*
	Stilt Sandpiper	*Calidris himantopus*
	Short-billed Dowitcher	*Limnodromus griseus*
	Common Snipe	*Capella gallinago*
	American Woodcock	*Philohela minor*
	Red-necked Phalarope	*Lobipes lobatus*
Laridae (Gulls and Terns)	Laughing Gull	*Larus atricilla*
	Bonaparte's Gull	*Larus philadelphia*
	Ring-billed Gull	*Larus delawarensis*
	Herring Gull	*Larus argentatus*
	Great Black-backed Gull	*Larus marinus*
	Black-legged Kittiwake	*Rissa tridactyla*
	Royal Tern	*Sterna maxima*
	Sandwich Tern	*Sterna sandvicensis*
	Roseate Tern	*Sterna dougallii*
	Common Tern	*Sterna hirundo*
	Forster's Tern	*Sterna forsteri*
	Least Tern	*Sterna albifrons*
	Black Skimmer	*Rynchops niger*
Alcidae (Auks)	Thick-billed Murre	*Uria lomvia*
Columbidae (Pigeons and Doves)	Rock Dove	*Columba livia*
	Mourning Dove	*Zenaida macroura*
Cuculidae (Cuckoos)	Black-billed Cuckoo	*Coxxyzus erythropthalmus*
	Yellow-billed Cuckoo	*Coccyzus americanus*
Strigidae (Typical Owls)	Eastern Screech-Owl	*Otus asio*
	Great Horned Owl	*Bubo virginianus*
	Snowy Owl	*Nyctea scandiaca*
	Barred Owl	*Strix varia*
	Short-eared Owl	*Asio flammeus*
	Northern Saw-whet Owl	*Aegolius acadicus*
Caprimulgidae (Goatsuckers)	Common Nighthawk	*Chordiles minor*
Apodidae (Swifts)	Chimney Swift	*Chaetura pelagica*
Trochilidae (Hummingbirds)	Ruby-thr. Hummingbird	*Archilochus colubris*
Alcedinidae (Kingfishers)	Belted Kingfisher	*Megaceryle alcyon*

Table 12-3 (continued): Birds found at Wells NERR.

Family	Common Name	Scientific Name
Picidae (Woodpeckers)	Yellow-bellied Sapsucker	*Sphyrapicus varius*
	Downy Woodpecker	*Picoides pubescens*
	Hairy Woodpecker	*Picoides villosus*
	Northern Flicker	*Colaptes chrysoides*
	Pileated Woodpecker	*Dryocopus pileatus*
Tyrannidae (Tyrant Flycatchers)	Eastern Wood-Pewee	*Contopus virens*
	Yellow-bellied Flycatcher	*Empidonomus flaviventris*
	Acadian Flycatcher	*Empidonax virescens*
	Alder Flycatcher	*Empidonax alnorum*
	Least Flycatcher	*Empidonax minimus*
	Eastern Phoebe	*Sayornis phoebe*
	Great Crested Flycatcher	*Myiarchus crinitus*
	Eastern Kingbird	*Tyrranus tyrranus*
Laniidae (Shrikes)	Northern Shrike	*Lanius excubitor*
Vireonidae (Vireos)	Yellow-throated Vireo	*Vireo flavifrons*
	Blue-headed Vireo	*Vireo solitarius*
	Warbling Vireo	*Vireo gilvus*
	Red-eyed Vireo	*Vireo olivaceus*
Corvidae (Crows and Jays)	Gray Jay	*Perisoresu canadensis*
	Blue Jay	*Cyanocorax cristata*
	American Crow	*Corvus brachyrhynchos*
	Fish Crow	*Corvus ossifragus*
	Common Raven	*Corvus corax*
Alaudidae (Larks)	Horned Lark	*Eremophila alpestris*
Hirundinidae (Swallows and Martins)	Purple Martin	*Progne subis*
	Tree Swallow	*Tachycineta bicolor*
	No. Rough-winged Swallow	*Stelgidopteryx serripennis*
	Bank Swallow	*Riparia riparia*
	Barn Swallow	*Hirundo rustica*
Paridae (Chickadees and Titmice)	Black-capped Chickadee	*Poecile atricapilla*
	Tufted Titmouse	*Baeolophus bicolor*
Sittidae (Nuthatches)	Red-breasted Nuthatch	*Sitta canadensis*
	White-breasted Nuthatch	*Sitta carolinensis*
Certhiidae (Creepers)	Brown Creeper	*Certhia americana*
Troglodytidae (Wrens)	Carolina Wren	*Thryothorus ludovicianus*
	House Wren	*Troglodytes aedon*
	Winter Wren	*Troglodytes troglodytes*
	Marsh Wren	*Cistothorus palustris*
Sylviidae (Gnatcatchers)	Blue-gray Gnatcatcher	*Polioptila caerulea*
Turdidae (Thrushes)	Eastern Bluebird	*Sialia sialis*
	Veery	*Catharus fuscescens*
	Gray-cheeked Thrush	*Catharus minimus*
	Swainson's Thrush	*Catharus ustulatus*
	Hermit Thrush	*Catharus guttatus*
	Wood Thrush	*Hylocichla mustelina*
	American Robin	*Turdus migratorius*
Mimidae (Thrashers and Mockinbirds)	Gray Catbird	*Dumtella carolinensis*
	Northern Mockingbird	*Mimus polyglottos*
	Brown Thrasher	*Toxostoma rufum*
Regulidae (Kinglets)	Ruby-crowned Kinglet	*Regulus calendula*
	Golden-crowned Kinglet	*Regulus satrapa*
Sturnidae (Starlings and Mynas)	European Starling	*Sturnus vulgaris*
	American Pipit	*Anthus rubescens*
Bombycillidae (Waxwings)	Cedar Waxwing	*Bombycilla cedrorum*
Parulidae (Wood Warblers)	Blue-winged Warbler	*Vermivora pinus*
	Tennessee Warbler	*Vermivora peregrina*
	Orange-crowned Warbler	*Vermivora celata*

Table 12-3 (continued): Birds found at Wells NERR.

Family	Common Name	Scientific Name
	Nashville Warbler	*Vermivora ruficapilla*
	Northern Parula	*Parula americana*
	Yellow Warbler	*Dendroica petechia*
	Chestnut-sided Warbler	*Dendroica pensylvanica*
	Magnolia Warbler	*Dendroica magnolia*
	Black-throated Blue Warbler	*Dendroica caerulescens*
	Yellow-rumped Warbler	*Dendroica coronata*
	Black-thr. Green Warbler	*Dendrocia virens*
	Blackburnian Warbler	*Dendroica fuca*
	Pine Warbler	*Dendroica pinus*
	Prairie Warbler	*Dendroica discolor*
	Palm Warbler	*Dendroica palmarum*
	Bay-breasted Warbler	*Dendroica castanea*
	Blackpoll Warbler	*Dendroica striata*
	Black-and-white Warbler	*Mniotilta varia*
	American Redstart	*Setophaga ruticilla*
	Ovenbird	*Seiurus aurocapillus*
	Northern Waterthrush	*Seiurus noveboracensis*
	Mourning Warbler	*Oporornnis philadelphia*
	Common Yellowthroat	*Geothlypis trichas*
	Hooded Warbler	*Wilsonia citrina*
	Wilson's Warbler	*Wilsonia pusilla*
	Canada Warbler	*Wilsonia canadensis*
Thraupidae (Tanangers)	Scarlet Tanager	*Piranga olivacea*
Emberizidae (New World Sparrows)	Eastern Towhee	*Pipilo erythrophthalmus*
	American Tree Sparrow	*Spizella arborea*
	Chipping Sparrow	*Spizella passerina*
	Field Sparrow	*Spizella pusilla*
	Vesper Sparrow	*Pooecetes gramineus*
	Lark Sparrow	*Chondestes grammacus*
	Savannah Sparrow	*Passerculus sandwichensis*
	Nelson's Sh.-tailed Sparrow	*Amophila nelsoni*
	Salt marsh Sh.-tailed Sparrow	*Ammodramus caudacutus*
	Seaside Sparrow	*Ammodramus maritimus*
	Song Sparrow	*Melospiza melodia*
	Lincoln's Sparrow	*Melospiza lincolnii*
	Swamp Sparrow	*Melospiza georgiana*
	White-throated Sparrow	*Zonotrichia albicollis*
	White-crowned Sparrow	*Zonotrichia leucophrys*
	Dark-eyed Junco	*Junco hyemalis*
	Lapland Longspur	*Calcarius lapponicus*
	Snow Bunting	*Plectophenax nivalis*
Cardinalidae (Cardinals)	Northern Cardinal	*Cardinalis cardinalis*
	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
	Indigo Bunting	*Passerina cyanea*
Icteridae (Blackbirds and Orioles	Bobolink	*Dolichonyx oryzivorus*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Eastern Meadowlark	*Sturnella magna*
	Common Grackle	*Quiscalus quiscula*
	Brown-headed Cowbird	*Molothrus ater*
	Orchard Oriole	*Icterus spurius*
	Baltimore Oriole	*Icterus galbula*
Fringillidae (Finches)	Purple Finch	*Carpodacus purpureus*
	House Finch	*Carpodacus mexicanus*
	Common Redpoll	*Carduelis flammea*
	American Goldfinch	*Carduelis tristis*
Passeridae (Old World Sparrows)	House Sparrow	*Passer domesticus*

Chapter 13

Mammals

Charles Lubelczyk and Kathleen M. O'Brien

Southern Maine is recognized as the most ecologically diverse region of Maine, both in floral and faunal communities (Krohn *et al*. 1998). The decline of widespread agriculture and pasturage since the 1800's has resulted in many areas reverting to forest (mixed softwoods and hardwoods) and field habitat of different successional stages. These habitats, interspersed with many types of wetlands, provide for a rich community of mammals in southern Maine. Situated in the South Coastal biophysical region of Maine (McMahon and Bernard 1993), Wells has many plants and animals that are common to both more northerly and more southerly locations. In this chapter we shall provide an overview of the mammals found within the habitats of the Wells National Estuarine Research Reserve (Wells NERR) and surrounding areas, and management implications for species of interest.

History of Studies at Wells NERR

Limited studies of mammal populations have occurred at Wells NERR. The most extensively studied mammal at the Reserve has been the white-tailed deer (*Odocoileus virginianus*). The impact of white-tailed deer on forest songbirds, vegetation communities, and their role in the enzootic cycle of Lyme disease has been well documented. In brief, deer are viewed by many researchers as a keystone herbivore in many ecological communities (Waller and Alverson 1997). Deer densities above 7.9 km^{-2} have been attributed to declines in forest songbird abundance (DeCalesta 1994) and have been shown to alter the composition of the forest plant community in favor of browse-resistant or unpalatable vegetation (Redding 1995). Rich (1992), using spotlighting censuses along transects, estimated the density of deer on Wells NERR to be above 60 mi^{-2} (23.1 km^{-2}). A later study by Rand *et al*. (2003) found a strong relationship between deer density and abundance of the Lyme disease vector tick *Ixodes scapularis*, commonly known as the deer tick (Fig. 13-1). This study, estimating deer density based on

White-tailed deer at Wells NERR. Photo Frank Wolfe.

pellet count censuses, estimated the number of deer in the vicinity of Wells NERR to be over 40 km^{-2}.

In addition to the role of white-tailed deer's role in the ecology of Lyme disease, the role of small mammal communities has also been examined. Rand *et al.* (1998) noted the presence of sub-adult deer ticks on small mammals at Wells NERR. In particular, abundance of ticks was greatest on two species of rodents, the white-footed mouse (*Peromyscus leucopus)* and eastern chipmunk (*Tamias striatus*). Hawks (1992) studied the relationship between the white-footed mouse and deer tick as well, finding that Wells NERR had greater burdens of ticks on its mice than a well-established comparison site at Crane's Beach in Ipswich, Massachusetts.

Recently, much attention has been paid to the presence of the New England cottontail (*Sylvilagus transitionalis*)

The Reserve's Muskie Trail passes through forests and fields where the careful observer may encounter wild mammals. Photo Scott Richardson.

Embedded tick larvae on white-footed mouse ear (left). Photo Kevin Byron.

in southern Maine, a species threatened with habitat loss from maturation of forests (Barbour and Litvaitis 1993), habitat fragmentation and scramble competition with a related but introduced species, the eastern cottontail (*Sylvilagus floridanus*) (Probert and Litvaitis 1996). Within Maine, however, the eastern cottontail has not been documented in the wild (Litvaitis *et al.* 2003), making Maine a potentially important refuge for New England cottontail. This lagomorph is proposed for listing under the State Endangered Species Act and has been designated as an official Candidate Species under the Federal Endangered Species Act. Wells NERR has been recognized as a crucial patch of habitat for this species, particularly for its thicket habitat dominated by alder, apple and honeysuckles (Barbour and Litvaitis 1993). Currently, densities are not estimated for this mammal on the Reserve. However, in the winter of 2005 / 2006 the presence of New England cottontail was confirmed with pellet DNA analysis and winter tracking (USFWS, personal communication).

Upland Habitats

Forest

Very few species of forest habitat specialists exist on the Reserve. Throughout the forested habitat of the Reserve, a diverse small mammal community exists which includes white-footed mice, pine voles (*Microtus pinetorum*), boreal red-backed voles (*Clethrionomys gapperi*), woodland jumping mice (*Napeaozapus insignis*), masked shrews (*Sorex cinereus*), short-tailed shrews (*Blarina brevicauda*), least shrews (*Cryptotis parva*), gray squirrels (*Sciurus carolinensis*), red squirrels (*Tamiasciurus hudsoni-*

A boreal red-backed vole carrying an embedded, engorged tick. Inset: close-up view of the embedded tick. Photo Maggie Desch.

cus), eastern chipmunks (*Tamias striatus*) and southern flying squirrel (*Glaucomys volans*). The southern bog lemming (*Synaptomis cooperi*) has been reported from the region but no specimens have been recorded from Wells NERR. This small mammal community supports a large population of predators, both avian and mammalian, including raptors but also wild canids such as the red fox (*Vulpes vulpes*) and coyote (*Canis latrans*). Mustelids such as ermine or short-tailed weasel (*Mustela erminea*), long-tailed weasel (*Mustela frenata*), fisher (*Martes pennanti*), and striped skunk (*Mephitis mephitis*), as well as raccoons (*Procyon lotor*) also benefit from this prey base. Other predators that might be found on the Reserve on occasion include bobcats (*Lynx rufus*), mink (*Mustela vison*), and gray fox (*Urocyon cinereoargenteus*). Cervids such as deer are abundant in many habitats, frequenting late successional and second-growth forests for cover and oak-maple forests for mast in the fall. Moose are an occasional presence on the Reserve, utilizing deciduous trees for browse.

Oak-pine forests: One of the few mammals truly associated with eastern white pine (*Pinus strobus*) on Wells NERR is the porcupine. This herbivore utilizes conifer trees for food and may damage limbs of trees by gnawing on young branches. Although both the red squirrel and the boreal red-backed vole are considered more typical in coniferous habitats, they are also typical of other forest types at Wells NERR.

Oak-pine forests and second-growth forests provide suitable nesting habitats for bats that use tree cavities and snags. Although no systematic survey of bat populations have been conducted at Wells NERR, southern Maine is home to many species of Chiroptera including the little brown myotis (*Myotis lucifugus*), the northern long-eared

The eastern chipmunk, Tamias striatus, is often seen in the upland forests of Wells NERR. Photo Ward Feurt.

bat (*Myotis septenrionalis*), big brown (*Eptisicus fuscus*), eastern pipistrelle (*Pipistrellus subflavus*), and the red bat (*Lasiurus borealis*) among others. Portions of these forests adjacent to fields also provide hibernation dens for the woodchuck (*Marmota monax*). Mast deposited from the canopies of oaks (*Quercus* spp.) and maples (*Acer* spp.), the dominant trees in these forests, are an important food source for a wide variety of mammals and birds, and complex interactions are believed to exist in the cycles of mast production and abundance of these forest animals (Jones *et al*. 1998, Ostfeld 2002).

Fields and Shrublands

Managed fields are frequented by high densities of meadow voles (*Microtus pennsylvanicus*). Runs of these abundant rodents are seen throughout field habitat, and attract predators such as foxes and coyotes during evening hours.

Successional thickets, having a minimum stem density of shrubs or small trees of > 10,000 stems per hectare, and a preferred stem density of > 20,000 stems per hectare, are ideal habitat for New England cottontail. While small patches of habitat less than 2 ha may be occupied, they are prone to local extinction. Management efforts should also be directed towards management of core habitats of greater than 10 ha or clusters of core habitats (Barbour and Litvaitis 1993; Litvaitis and Villafeurte 1996, Litvaitis *et al*. 2001, 2003, Litvaitis and Tash 2006). Although New England cottontail has often been associated with exotic, invasive shrub species such as honeysuckle (*Lonicera* spp.), Japanese barberry (*Berberis thunbergii*) and multiflora rose (*Rosa multiflora*), it is unknown if these plants provide high-quality habitat and sufficient winter browse. It is recommended that management actions be geared towards the promotion of native shrublands and small trees such as gray birch, red maple, wild apple trees, aspen, raspberry, blackberry, willow and blueberries, etc. as important cover and food species as well (Litvaitis and Tash 2006). At the Reserve, apples, common in areas previously maintained as orchards, are an important food source along with red maple (*Acer rubrum*), highbush blueberry (*Vaccinium corymbosum*), aspen (*Populus tremuloides*) and black cherry (*Prunus serotina*), common saplings in successional fields at Wells NERR.

Wetland

Riverine habitats adjacent to Wells NERR support muskrats (*Ondatra zibethicus*), mink (*Mustela vison*) and occasionally river otters (*Lontra canadensis*). As yet, beaver (*Castor canadensis*), while present in southern Maine, are not on the Reserve, but are likely found in the watersheds of the Reserve's estuaries.

Flying squirrels are found at the Reserve. Photo James Dochtermann.

Harbor seal pup hauled out on the Little River marsh. Photo Sue Bickford.

Marine

Pinnipeds are the only marine mammals that are seen on the terrestrial portions of Wells NERR. Harbor seals (see photo) may be seen on beaches and the high marsh edge as well as in the estuaries, but the Gulf of Maine is home to twenty-two species of whales and five other species of seals, including right whales (*Eubalaena* sp.), minke whales (*Balenoptera acutorostrata*), common dolphins (*Delphinus delphinus*), bottlenosed dolphin (*Tursiops truncatus*), and gray seals (*Halichoerus grypus*). Seals use the estuary as a haul-out area, and are occasionally stranded there.

Research Overview

Deer

The abundance of white-tailed deer (*Odocoileus virginianus*) in south coastal Maine has been a concern of both natural resource managers and public health professionals. In addition to its role in the ecology of Lyme disease, deer overabundance has been linked to songbird declines in northeastern forests (DeCalesta 1994); see Chapter 12. It has been estimated that deer densities over 7.9 km^{-2} begin to show adverse effects on the vegetation community and impact bird populations, primarily those species utilizing the ground and lower shrub layers (DeCalesta 1994, Redding 1995). The most recent estimate of deer density on Wells NERR far exceed this (Rand *et al.* 2003). Rand *et al.* (2003) found that higher deer densities were correlated with higher tick densities at sites in southern Maine (Fig. 13-1). Until 2002, deer hunting was prohibited on Wells NERR because of its status as a state game sanctuary, a provision that dated back to the 1930's.

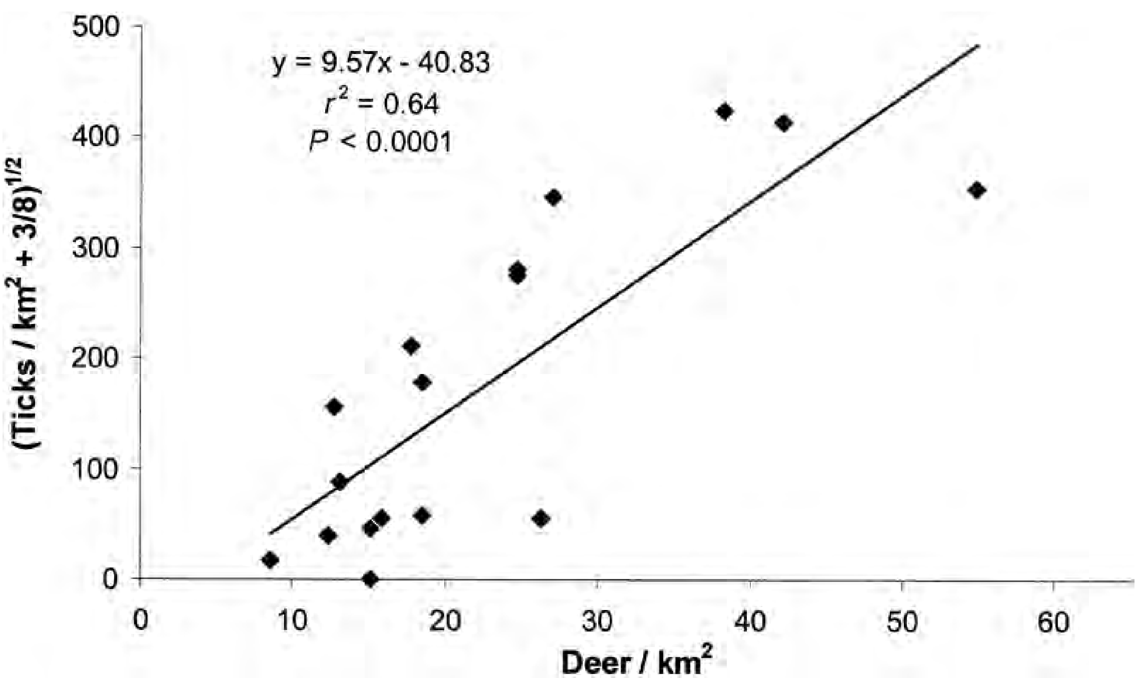

Figure 13-1: The relationship of deer km^{-2}, estimated on the basis of pellet group surveys in southern Maine, and the number of adult *I. scapularis* km^{-2} flagged from vegetation, within eight 5.2 km^2 study sites, 1998-2000 (Rand *et al.* 2003). Figure: Entomological Society of America.

A New England cottontail huddled in a thicket. Photo Ward Feurt.

Habitat Loss

In addition to being the most ecologically diverse region of Maine, south coastal Maine also contains the highest human population. Undisturbed areas are rare in this region of Maine and coastal parcels have increased in economic value, making landscape conservation much more difficult as development pressures increase.

Research Needs

Much more research is needed on the sustainability of New England cottontail populations. The possibility of undesirable plant species (invasive exotics) benefiting this animal might mitigate control measures on these plants (barberries, honeysuckles, etc). In addition, the role of invasive plants in providing shelter and as potential food sources is also unknown. Population dynamics of New England cottontail, including survivorship, dispersal and densities are currently unknown for the animals occurring at the Reserve. Native and exotic shrub habitat should be experimentally compared to determine their value for the cottontail and the many other native animal species that are associated with understory and successional shrub habitat.

A basic inventory of those species requiring more study at Wells NERR (chiropterans, carnivores, etc) should be implemented. Some species such as fisher (*Martes pennanti*) were historically thought to exist only in large tracts of mature forest but are thriving in southern Maine, especially in areas thought of as fragmented forest.

Management Recommendations

Wells NERR's decision in 2002 to implement a limited bow hunt to control deer in cooperation with the US Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildlife (MEDIFW) was an initial step to managing the Reserve's overabundant deer population. MEDIFW has set a target density of 15 deer mi^{-2} ($\approx$ 8 km^{-2}) for the wildlife management zone that encompasses Wells, Maine (Lavigne 1999). This is in response, primarily, to issues of public health (Lyme disease), forest health (vegetation impacts and forest bird impacts), and residential impacts from deer that migrate from the Reserve. Although, to date, less than a hundred deer have been harvested, this process should continue with the cooperation of the stakeholders involved. Ultimately, if this approach does not produce desired results, other means of controlling deer numbers at Wells NERR should be explored.

Winter snows at Wells NERR allow many opportunities for tracking. These prints most likely belong to a Racoon. Photo Susan Bickford.

In 2006, the Wells NERR and Rachel Carson NWR formed a partnership to devise strategies for developing a shrubland management plan to improve habitat for the New England cottontail. A plan was developed that suggests blocks of connected ares where shrubland management continues, native plants are promoted, apple trees released and alder regenerated. Removal of invasive plants should continue, taking care that winter cover for the New England cottontail is not eliminated before other suitable cover is established.

Although some invasives, such as honeysuckles, could be important for cover, other species such as Asiatic bittersweet (*Celastrus orbiculatus*) may aggressively impede potential food resources such as apples. Management of bittersweet should be conducted—either through cutting, mowing, or application of herbicide in thickly infested habitats—in order to release apples and cherries. Areas which are currently not occupied by invasive plants should be kept clean, by pulling, digging or herbiciding undesirable plants to keep the problem under control. Where invasive cover is light, and there are native shrubs present, exotics should be removed. Infested areas, with documented cottontail usage, may require more research and planning to direct management actions.

Thick growth of invasive barberry may be facilitated by over-browsing of native plants by white-tailed deer. Photo Charles Lubelczyk.

For the management of the federally threatened piping plover (*Charadrius melodus*) or the State endangered least tern (*Sterna antillarum*), it is possible that on occasion predatory mammals may need to be controlled. It is recommended that this control be conducted on as-needed basis.

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Table 13-1: Mammals found at Wells NERR.

Family	Common Name	Scientific Name
Canidae	Coyote	*Canus latrans*
	Gray Fox	*Urocyon cinereoargenteus*
	Red Fox	*Vulpes vulpes*
Cricetidae	Muskrat	*Ondatra zibethicus*
Didelphidae	Virginia Opossum	*Didelphis viginiana*
Felidae	Bobcat	*Felis rufus*
Hystricidae	Porcupine	*Erethizon dorsatum*
Leporidae	Northeast Cottontail	*Sylvilagus transitionalis*
	Eastern Cottontail	*Sylvilagus floridanus*
Mustelidae	Ermine (Short-Tailed Weasel)	*Mustela erminea*
	Fisher	*Martes pennanti*
	Masked Shrew	*Sorex cinereus*
	Mink	*Mustela sp.*
	River Otter	*Lontra canadensis*
	Striped Skunk	*Mephitis mephitis*
Phocidae	Harbor Seal	*Phoca vitulina*
Procyonidae	Raccoon	*Procyon lotor*
Rodentia	Beaver	*Castor canadensis*
	Eastern Chipmunk	*Tamias striatus*
	Gray Squirrel	*Sciurus carolinensis*
	Hairy Tailed Mole	*Parascalops breweri*
	Little Brown Bat	*Myotis lucifugus*
	Meadow Vole	*Microtus pennsylvanicus*
	Northern Flying Squirrel	*Glaucomys sabrinus*
	Red Squirrel	*Tamiasciurus hudsonicus*
	Southern Flying Squirrel	*Glavcomys volans*
	Star-Nosed Mole	*Condylura cristata*
	White-Footed Mouse	*Peromyscus leucopus*
	Woodchuck (Groundhog)	*Marmota monax*
Soricidae	Short-Tailed Shrew	*Blarina brevicauda*
Ungulata	White-Tailed Deer	*Odocoileus virginianus*
Ursidae	Black Bear	*Urus americanus*