4 Habitats of Species of Greatest Conservation Need

A: Introduction and List of SWAP Habitats

To discuss the threats and conservation actions for 569 Species of Greatest Conservation Need, we have assigned each species to one or more of 24 SWAP Habitats (Table 4-1; Figure 4-1). These SWAP Habitats do not, in general, correspond to what are usually called natural communities (Swain and Kearsley 2015), but are much more generalized. As such, they serve as convenient categories within which to discuss the SGCN. A species was assigned to a SWAP Habitat if the habitat is a major and essential component of the species' life history. For example, Marbled Salamanders breed only in vernal pools, so they were assigned to the Vernal Pool SWAP Habitat. Outside of the breeding season, however, they spend their lives in two types of upland forests, Transitional Hardwoods-White Pine Upland Forest or Central Hardwoods-White Pine Upland Forest, and are assigned to both those SWAP Habitats as well. Occasionally, Marbled Salamanders may be found crossing shorts stretches of shrubland on the way to breed in vernal pools, or might use the edge or the drier parts of forested swamps, but neither shrublands nor forested swamps are major or essential parts of their life history, and therefore they are not assigned to those SWAP Habitats.

The 24 SWAP Habitats are broken into three categories: large-scale, medium-scale, and small-scale. These reflect the relative sizes in acreage of the SWAP Habitats in each, and are intended simply to guide the user of this SWAP as to the extent of each SWAP Habitat across the Massachusetts landscape.

In this 2015 update, we use almost the same list of SWAP Habitats as in the 2005 Massachusetts SWAP, except that we have subdivided Upland Forest into the three major types of forests in Massachusetts (see Table 4-1) and changed the 2005 Pitch Pine/Scrub Oak habitat to Pitch Pine-Oak Upland Forest, which better reflects the variety in this forest type on our landscape.

Table 4-1: List of Massachusetts SWAP Habitats

Large-scale Habitats
Connecticut and Merrimack Mainstems
Large and Mid-sized Rivers
Marine and Estuarine Habitats
Transition Hardwoods-White Pine Upland Forest
Northern Hardwoods-Spruce-Fir Upland Forest
Central Hardwoods-White Pine Upland Forest
Pitch Pine-Oak Upland Forest
Large Unfragmented Landscape Mosaics
Medium-scale Habitats
Small Streams
Shrub Swamps
Forested Swamps
Lakes and Ponds
Salt Marsh
Coastal Dunes, Beaches, and Small Islands
Grasslands
Young Forests and Shrublands
Riparian Forest
Small-scale Habitats
Vernal Pools
Coastal Plain Ponds
Springs, Caves, and Mines
Peatlands and Associated Habitats
Marshes and Wet Meadows
Rocky Coastlines
Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats

For each SWAP Habitat, Section C, below, provides the following:

- A description, including a map of its distribution;
- A list of associated SGCN (note that individual SGCN may be associated with more than one SWAP Habitat);
- A list and narrative of the SGCN assigned to the SWAP Habitat;
- Generalized and specific threats to the Habitat, using the IUCN (International Union for the Conservation of Nature) threat classification scheme (Salafsky et al. 2008; see Box 4-1), as recommended by the Northeast Lexicon for SWAP updates (Crisfield and Northeast Fish and Wildlife Diversity Technical Committee 2013);
- Recommended conservation actions for the Habitat, using a modified and shortened version of the TRACS action classification system, as recommended by the Northeast Lexicon (TRACS is the abbreviation for the Wildlife Tracking and Reporting Actions for the Conservation of Species, the tracking and reporting system used by the U.S. Fish & Wildlife Service Wildlife and Sport Fish Restoration program to collect data on conservation actions funded by the program's grants).

Note that the four types of Upland Forest are discussed together, with the types broken out as needed.

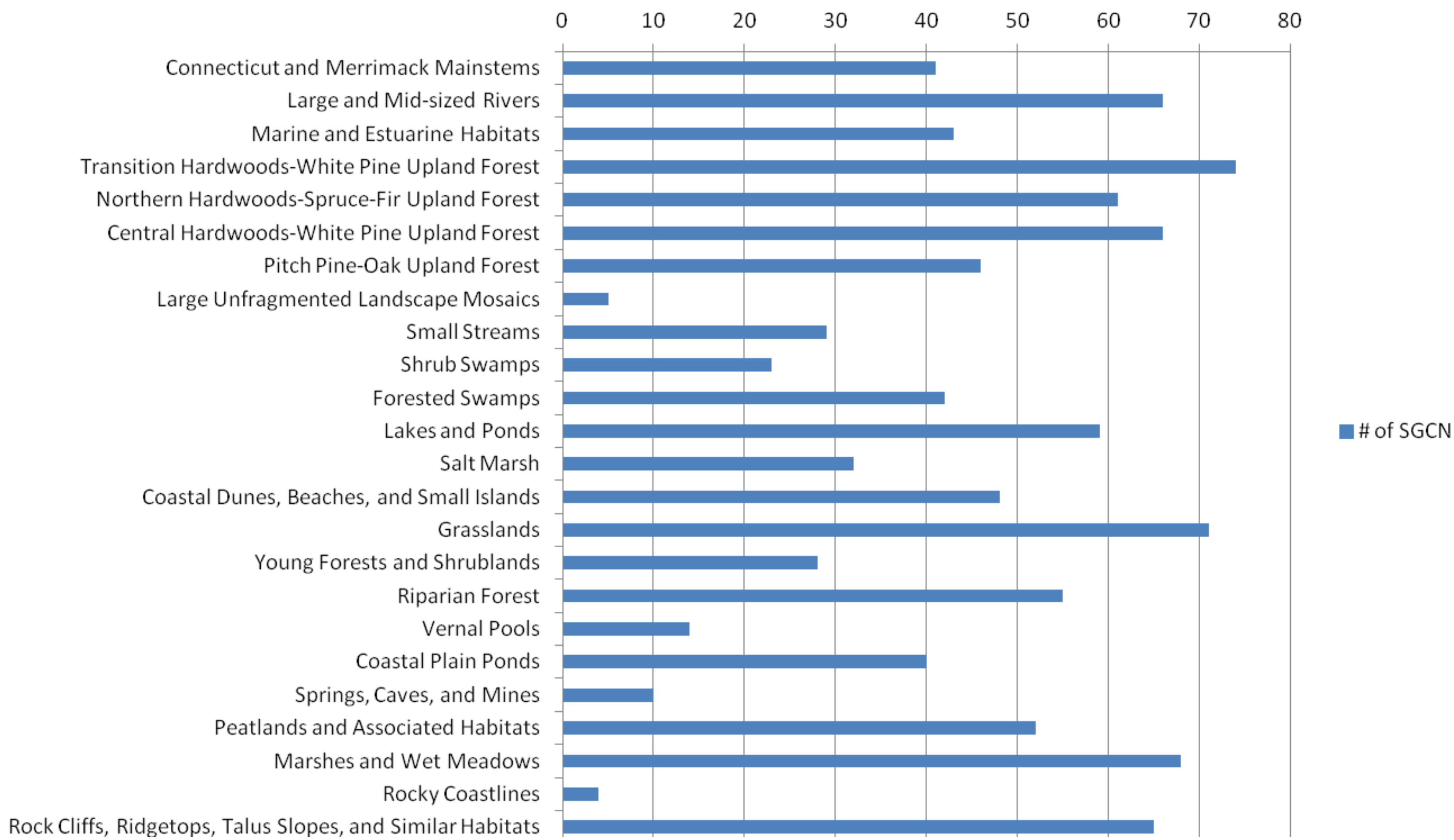


Figure 4-1: Number of SCGN assigned to each SWAP Habitat.

Box 4-1: IUCN Threat Classification Scheme

Source: http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme

1 Residential & commercial development
- 1.1 Housing & urban areas
- 1.2 Commercial & industrial areas
- 1.3 Tourism & recreation areas

2 Agriculture & aquaculture
- 2.1 Annual & perennial non-timber crops
  - 2.1.1 Shifting agriculture
  - 2.1.2 Small-holder farming
  - 2.1.3 Agro-industry farming
  - 2.1.4 Scale Unknown/Unrecorded
- 2.2 Wood & pulp plantations
  - 2.2.1 Small-holder plantations
  - 2.2.2 Agro-industry plantations
  - 2.2.3 Scale Unknown/Unrecorded
- 2.3 Livestock farming & ranching
  - 2.3.1 Nomadic grazing
  - 2.3.2 Small-holder grazing, ranching or farming
  - 2.3.3 Agro-industry grazing, ranching or farming
  - 2.3.4 Scale Unknown/Unrecorded
- 2.4 Marine & freshwater aquaculture
  - 2.4.1 Subsistence/artisinal aquaculture
  - 2.4.2 Industrial aquaculture
  - 2.4.3 Scale Unknown/Unrecorded

3 Energy production & mining
- 3.1 Oil & gas drilling
- 3.2 Mining & quarrying
- 3.3 Renewable energy

4 Transportation & service corridors
- 4.1 Roads & railroads
- 4.2 Utility & service lines
- 4.3 Shipping lanes
- 4.4 Flight paths

5 Biological resource use
- 5.1 Hunting & collecting terrestrial animals
  - 5.1.1 Intentional use (species being assessed is the target)
  - 5.1.2 Unintentional effects (species being assessed is not the target)
  - 5.1.3 Persecution/control
  - 5.1.4 Motivation Unknown/Unrecorded
- 5.2 Gathering terrestrial plants
  - 5.2.1 Intentional use (species being assessed is the target)
  - 5.2.2 Unintentional effects (species being assessed is not the target)
  - 5.2.3 Persecution/control
  - 5.2.4 Motivation Unknown/Unrecorded
- 5.3 Logging & wood harvesting
  - 5.3.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
  - 5.3.2 Intentional use: large scale (species being assessed is the target) [harvest]

Box 4-1: IUCN Threat Classification Scheme, continued

5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest]
5.3.4 Unintentional effects: large scale (species being assessed is not the target) [harvest]
5.3.5 Motivation Unknown/Unrecorded
5.4 Fishing & harvesting aquatic resources
5.4.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
5.4.2 Intentional use: large scale (species being assessed is the target) [harvest]
5.4.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest]
5.4.4 Unintentional effects: large scale (species being assessed is not the target) [harvest]
5.4.5 Persecution/control
5.4.6 Motivation Unknown/Unrecorded
6 Human intrusions & disturbance
6.1 Recreational activities
6.2 War, civil unrest & military exercises
6.3 Work & other activities
7 Natural system modifications
7.1 Fire & fire suppression
7.1.1 Increase in fire frequency/intensity
7.1.2 Suppression in fire frequency/intensity
7.1.3 Trend Unknown/Unrecorded
7.2 Dams & water management/use
7.2.1 Abstraction of surface water (domestic use)
7.2.2 Abstraction of surface water (commercial use)
7.2.3 Abstraction of surface water (agricultural use)
7.2.4 Abstraction of surface water (unknown use)
7.2.5 Abstraction of ground water (domestic use)
7.2.6 Abstraction of ground water (commercial use)
7.2.7 Abstraction of ground water (agricultural use)
7.2.8 Abstraction of ground water (unknown use)
7.2.9 Small dams
7.2.10 Large dams
7.2.11 Dams (size unknown)
7.3 Other ecosystem modifications
8 Invasive & other problematic species, genes & diseases
8.1 Invasive non-native/alien species/diseases
8.1.1 Unspecified species
8.1.2 Named species
8.2 Problematic native species/diseases
8.2.1 Unspecified species
8.2.2 Named species
8.3 Introduced genetic material
8.4 Problematic species/diseases of unknown origin
8.4.1 Unspecified species
8.4.2 Named species
8.5 Viral/prion-induced diseases
8.5.1 Unspecified "species" (disease)
8.5.2 Named "species" (disease)
8.6 Diseases of unknown cause

Box 4-1: IUCN Threat Classification Scheme, continued

9 Pollution
- 9.1 Domestic & urban waste water
  - 9.1.1 Sewage
  - 9.1.2 Run-off
  - 9.1.3 Type Unknown/Unrecorded
- 9.2 Industrial & military effluents
  - 9.2.1 Oil spills
  - 9.2.2 Seepage from mining
  - 9.2.3 Type Unknown/Unrecorded
- 9.3 Agricultural & forestry effluents
  - 9.3.1 Nutrient loads
  - 9.3.2 Soil erosion, sedimentation
  - 9.3.3 Herbicides and pesticides
  - 9.3.4 Type Unknown/Unrecorded
- 9.4 Garbage & solid waste
- 9.5 Air-borne pollutants
  - 9.5.1 Acid rain
  - 9.5.2 Smog
  - 9.5.3 Ozone
  - 9.5.4 Type Unknown/Unrecorded
- 9.6 Excess energy
  - 9.6.1 Light pollution
  - 9.6.2 Thermal pollution
  - 9.6.3 Noise pollution
  - 9.6.4 Type Unknown/Unrecorded

10 Geological events
- 10.1 Volcanoes
- 10.2 Earthquakes/tsunamis
- 10.3 Avalanches/landslides

11 Climate change & severe weather
- 11.1 Habitat shifting & alteration
- 11.2 Droughts
- 11.3 Temperature extremes
- 11.4 Storms & flooding
- 11.5 Other impacts

12 Other options
- 12.1 Other threat

B: Comparison to Regional Habitat Classification Systems

Table 4-2, below, provides a crosswalk between the Northeastern Regional Habitat Macrogroups (Gawler 2008) and the Massachusetts SWAP Habitats. These regional terrestrial habitats are based on the Northeastern Terrestrial Wildlife Habitat Classification, a classification scheme developed by The Nature Conservancy at the direction of the Northeast Fish and Wildlife Diversity Techynical Committee, to facilitate comparisons among SWAP habitat types used by the northeastern states.

Table 4-2: Massachusetts and Regional Terrestrial Habitats Comparison

Massachusetts SWAP Habitat	Northeast Terrestrial Regional Habitat Macrogroups
Large-scale Habitats	
Connecticut and Merrimack Mainstems	NA
Large and Mid-sized Rivers	NA
Marine and Estuarine Habitats	NA
Upland Forest (all four subtypes)	Central Oak-Pine Northern Hardwood & Conifer Boreal Upland Forest
Large Unfragmented Landscape Mosaics	NA
Medium-scale Habitats	
Small Streams	NA
Shrub Swamps	Wet Meadow/Shrub Marsh
Forested Swamps	Central Hardwood Swamp Northern Swamp
Lakes & Ponds	NA
Salt Marsh	Salt Marsh
Coastal Dunes, Beaches, and Small Islands	Intertidal Shore
Grasslands	Ruderal Shrubland & Grassland Coastal Grassland & Shrubland
Young Forests and Shrublands	Ruderal Shrubland & Grassland Coastal Grassland & Shrubland
Riparian Forest	Northeastern Floodplain Forest
Small-scale Habitats	
Vernal Pools	NA
Coastal Plain Ponds	NA
Springs, Caves and Mines	NA
Peatlands and Associated Habitats	Coastal Plain Swamp Northern Peatland
Marshes and Wet Meadows	Wet Meadow/Shrub Marsh Modified/Managed Marsh
Rocky Coastlines	Rocky Coast
Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats	Outcrop & Summit Scrub Cliff & Talus

The aquatic habitats in Table 4-3 are crosswalked to the Northeast Aquatic Habitat Classification System (Olivero and Anderson 2008) to the extent possible. Note this classification scheme is being revised to describe lakes and ponds better; this revision is not incorporated below.

Table 4-3: Massachusetts and Regional Aquatic Habitats Comparison

Massachusetts SWAP Habitat	Northeast Aquatic Habitats
Large-scale Habitats	
Connecticut and Merrimack Mainstems	Large/Great River
Large and Mid-sized Rivers	Medium River
Marine and Estuarine Habitats	NA
Upland Forest – all subtypes	NA
Large Unfragmented Landscape Mosaics	NA
Medium-scale Habitats	
Small Streams	Headwater/Creek Small River
Shrub Swamps	NA
Forested Swamps	NA
Lakes and Ponds	NA
Salt Marsh	NA
Coastal Dunes, Beaches, and Small Islands	NA
Grasslands	NA
Young Forests and Shrublands	NA
Riparian Forest	NA
Small-scale Habitats	
Vernal Pools	NA
Coastal Plain Ponds	NA
Springs, Caves, and Mines	NA
Peatlands and Associated Habitats	NA
Marshes and Wet Meadows	NA
Rocky Coastlines	NA
Rock Cliffs, Ridgetops, Talus Slopes, & Similar Habitats	NA

C: Massachusetts SWAP Habitats

Connecticut and Merrimack Mainstems

Habitat Description

The mainstems of the Connecticut and Merrimack rivers (Figure 4-2) are orders of magnitude larger, in several ways, than other rivers in Massachusetts and, thus, merit their own SWAP Habitat. One such indicator is the fact that they are the only rivers in the Commonwealth known to support the federally Endangered Shortnose Sturgeon.

The 410-mile-long Connecticut River is New England's longest river. Its headwaters are Fourth Connecticut Lake at the Canadian border, and it empties into Long Island Sound at Old Saybrook, Connecticut. The entire watershed encompasses an area of over 11,000 square miles (more than twice the area of Massachusetts), includes parts of four states (Connecticut, Massachusetts, New Hampshire, and Vermont), and is home to 2.3 million people. The river drops 2,400 feet from its source to the sea, and has a daily average flow of nearly 16,000 cubic feet per second (cfs). The flow has ranged as high as 282,000 cfs and as low as 971 cfs. The lower 60 miles of the River are tidal, with the boundary between salt water and fresh water about 17 miles inland from its mouth under normal conditions. Its waters represent 70% of the freshwater inflow to Long Island Sound. The Connecticut River has 38 major tributaries, 26 of which drain 100 square miles or more. All told, there are over 20,000 miles of streams in the watershed. Within Massachusetts, there are 65 miles of mainstem river habitat. About one-third of that length is impounded behind two major hydroelectric dams, one at Holyoke and one at Turners Falls.

The Merrimack River watershed, the fourth largest in New England, covers 5,010 square miles in New Hampshire and Massachusetts. The river extends 180 miles from Profile Lake in the White Mountains of New Hampshire, where it begins as the Pemigewasset River, to Newburyport, Massachusetts, where it empties into the Atlantic Ocean, including 50 miles of mainstem in Massachusetts. The final 22 miles of the river, downstream of Haverhill, Massachusetts, are tidally influenced. The entire watershed includes all or parts of approximately 200 communities with a total population of 2 million people. About one-quarter, or 1,200 square miles, of the watershed is in Massachusetts, including all or part of 24 Massachusetts municipalities. The average discharge measured by the USGS gauge on the Merrimack River at Lowell is 7,562 cfs, with an extreme high of 173,000 cfs in 1936 and an extreme low of 199 cfs in 1923. The river is regulated by two large hydroelectric dams in Massachusetts, the Pawtucket Dam in Lowell and the Essex Dam in Lawrence.

These mainstem river habitats are characterized by wide, low-gradient streambeds meandering through broad river valleys with extensive flood plains. Rapid or riffle habitat is extremely rare and, on the Connecticut and Merrimack in Massachusetts, has been dammed for power generation. Channel formation occurs during periods of extreme flow (often described by the period of occurrence, e.g., 100-year or 500-year floods).

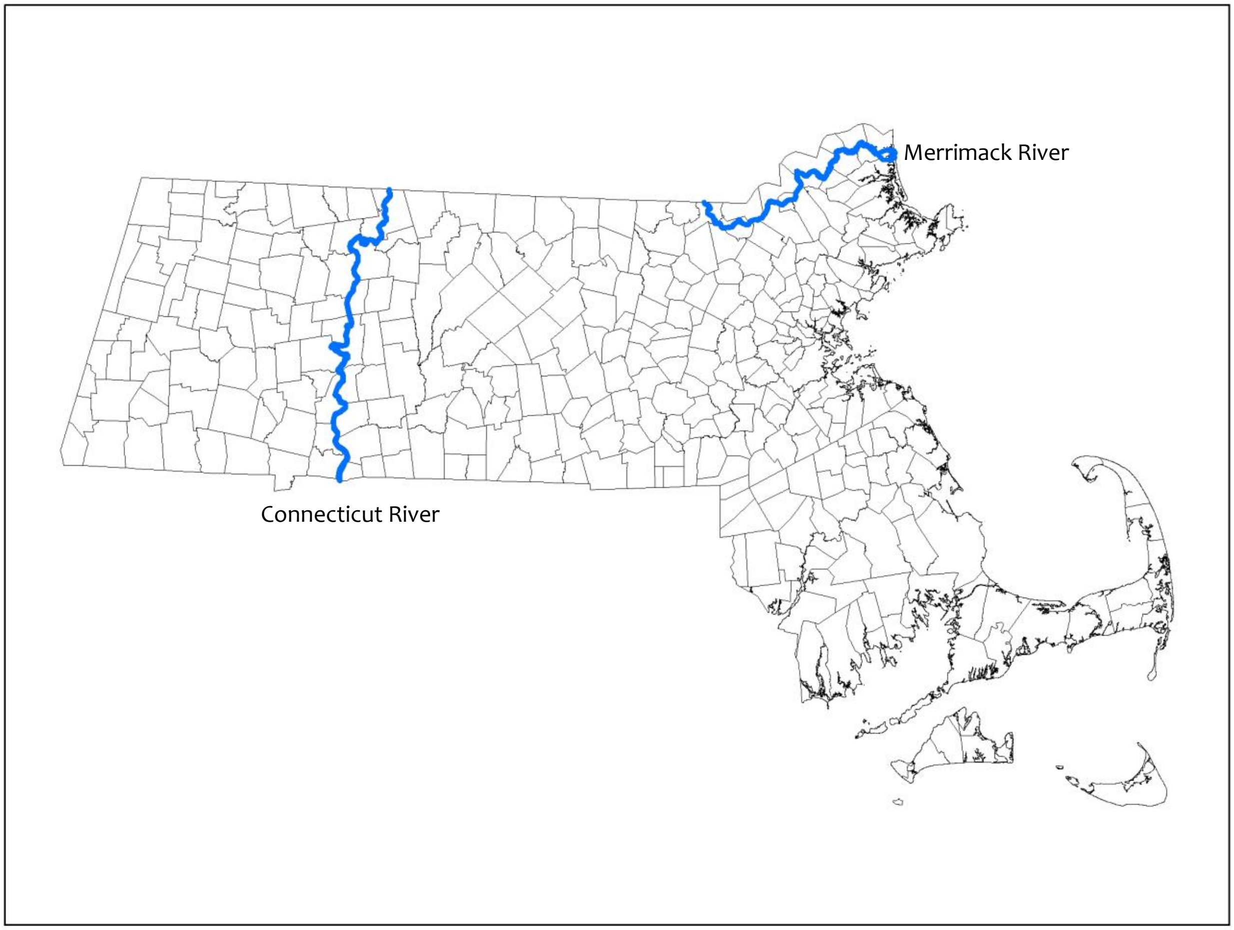


Figure 4-2: Connecticut and Merrimack River Mainstems in Massachusetts.

Species of Greatest Conservation Need in the Connecticut and Merrimack Mainstems

Forty-one SGCN are assigned to the Connecticut and Merrimack Mainstems habitat (Table 4.4).

Although classified as an anadromous fish, the Shortnose Sturgeon is almost never found in the open ocean. Instead, individuals spend their lives in the river mainstems undergoing migrations between discrete spawning, rearing, and feeding areas, including the estuary. Spawning occurs in the spring in rapidly moving sections of the river mainstems, now found only below the dams of these two major rivers. Atlantic Sturgeon are anadromous, entering large freshwater river systems to spawn during the spring. While there are no spawning populations of the Atlantic Sturgeon in Massachusetts, juvenile Atlantic Sturgeon can occasionally be found in the estuaries and lower portions of the major rivers during the summer months.

The Connecticut and Merrimack rivers each support river herring (Alewife and Blueback Herring) populations. The mainstem portions of these rivers are critical habitat for these species. River herring spawn in mainstem rivers and tributaries from April to mid-July when water temperatures range from 51° (Alewife) or 57° (Blueback Herring) to 81° F. Upstream distribution of adults is a function of habitat suitability and hydrologic conditions permitting access to these sites. Immediately after spawning, surviving adult river herring migrate rapidly downstream to return to the sea. Alewives are still-water spawners and focus their reproductive efforts in the tidal portions of the rivers. In addition to the mainstem, alewives also use spawning habitat in backwaters and impoundments. Spawning can occur over a range of substrates, such as gravel, sand, detritus, and submerged vegetation. Blueback Herring spawning sites include swift flowing sections of freshwater rivers, channel sections of fresh and brackish tidal rivers, and Atlantic coastal ponds over gravel and clean sand substrates. Blueback Herring in the Connecticut River basin migrate farther upstream in the mainstem (to Bellows Falls, Vermont) than do Alewives. Juvenile river herring occur in non-tidal and tidal freshwater and semi-brackish areas (mainstems and major tributaries) during spring and early summer, moving upstream during periods of decreased flows and encroachment of saline waters. Juveniles begin migrating from their nursery areas to the sea in the fall, cued by heavy rainfalls, high waters, or sharp declines in water temperatures.

The Connecticut and Merrimack rivers each support large, healthy American Shad populations. The mainstem portions of these rivers are critical habitat for this species. American Shad are anadromous, migrating from the ocean to freshwater specifically to reproduce. Adult shad enter rivers in the spring, mid-April through June, in the Connecticut and Merrimack. Spawning occurs in the river mainstems and their larger tributaries in the early summer. Spawning usually occurs over gently sloping areas with fine gravel or sandy bottoms. After spawning, adult shad return to the sea. Fertilized eggs are carried by river currents and hatch within a few days. Larvae drift with the current until they mature into juveniles that remain in nursery areas (mainstem rivers and their larger tributaries), feeding on zooplankton and terrestrial insects. By late fall, most juvenile shad migrate to near-shore coastal wintering areas. Some juvenile shad will remain in river mainstems and estuaries up to a year before entering the ocean.

The American Eel is a catadromous species, which spends most of its life in rivers, lakes, and estuaries, but migrates to the ocean to spawn. Populations of American Eel occur in both the Connecticut and Merrimack rivers. The mainstem portions of these rivers are important migratory routes, but also serve as the primary rearing habitat for some portion of the population. Some eels remain in the estuaries, but others migrate varying distances upstream, often for several hundred kilometers. American Eels will remain in the brackish and fresh waters of these rivers for the majority of their lives, at least 5 and possibly as many as 20 years. Mature eels migrate back to the waters of the Sargasso Sea to spawn. The migration occurs throughout autumn nights, with adults descending streams and rivers to the estuaries for January spawning in the warm Caribbean waters.

In Massachusetts, Eastern Silvery Minnows are found currently only in the Connecticut River above the Holyoke Dam. Once more common in this river, the population has apparently declined over the past few decades, possibly because of changes in river flows due to dams. Similarly, the Burbot in Massachusetts is currently found only in the Connecticut River and one small tributary to the Connecticut. Very few Burbot have even been found in the Massachusetts stretch of the Connecticut and it is unclear what the status of this population is in Massachusetts.

Both the Connecticut and Merrimack rivers support Sea Lamprey populations. The tributaries of these rivers are critical habitat for this species. Sea Lampreys are anadromous, migrating from the ocean to freshwater specifically to reproduce. Adult lampreys are parasitic, attaching themselves to a variety of oceanic fish species and feeding on their blood and body fluids. After two years at sea, lampreys enter rivers in the spring, mid-April through June in the Connecticut and Merrimack rivers. Spawning occurs in the tributaries in the early summer. Lampreys build shallow nests in the gravel bottom, deposit their eggs, and then die. Fertilized eggs hatch in about two weeks and the young (known as ammocoetes) drift with the current until they find suitable soft substrates, where they burrow into the stream bottom and live as filter feeders for 4 to 5 years. Eventually, ammocoetes transform into young adults that migrate to the ocean.

About twenty pairs of Bald Eagle nest along the Connecticut and Merrimack rivers. The first pair of nesting Bald Eagles along the Merrimack in recent years only took up residence in 2004. Both the Connecticut and Merrimack are used for summer feeding, migration, and over-wintering by all age classes of Bald Eagle.

Seven species of rare freshwater mussel are found in the mainstem of the Connecticut River. In Massachusetts, the Yellow Lampmussel is found only in the Connecticut River, and its distribution and abundance throughout the river may be affected by the presence and operation of the two large hydropower dams. The federally Endangered Dwarf Wedgemussel and state Endangered Brook Floater are historically known from the Connecticut River, but are currently presumed extirpated. The Creeper is also only known from historic or shell-only records in the Connecticut River. With the exception of a single individual in Hadley, the distribution of Tidewater Mucket appears to be limited to below the Holyoke Dam. Eastern Pondmussel can be locally abundant in the Connecticut River mainstem, particularly within the impoundment of the Holyoke Dam. Triangle Floater has been found in several locations throughout the length of the river in Massachusetts; however, it is typically found in low abundances, and below the Holyoke Dam it is known only from historic records. Alewife Floater and Eastern Lampmussel may also be locally abundant throughout the river in suitable habitats. Note that all but Yellow Lampmussel are also found in other waterbodies in Massachusetts, besides the Connecticut and Merrimack rivers.

Records of rare mussels in the Merrimack River mainstem are either historic (circa 1866), or shell-only records. The mainstem of the Merrimack once supported Yellow Lampmussel, Triangle Floater, Eastern Pondmussel, and Creeper populations, but these species were last observed in the river in the late 1800s. Currently, the only other known rare mussel records are from shells of Alewife Floater found in Methuen and Haverhill, below the farthest downstream dam in Lawrence. Though never reported from Massachusetts in the Merrimack, the Eastern Lampmussel is known historically from the mainstem of the Merrimack River upstream of Bedford, New Hampshire, and may be present in the Massachusetts portion of the river as well. The mussel fauna of the Merrimack River in Massachusetts needs further survey and attention to assess conservation priorities in this river.

Similarly, the Connecticut River was thought to support many more rare dragonfly species than the Merrimack River, but the Cobra Clubtail, Umber Shadowdragon, and Riverine Clubtail were discovered on the Merrimack during surveys in 2004, illustrating the need for more surveys for rare riverine odonates on these two rivers.

The Connecticut River supports the only populations of the Cobblestone and Puritan Tiger Beetles in Massachusetts. It is quite unlikely that these species could be found on the Merrimack in Massachusetts. Both beetles use bars of sorted substrate (cobbles and sand, respectively) along the river’s edge, and are highly susceptible to alterations in river flows, as well as human use of river banks. Both species, unfortunately, have experienced severe declines in recent years, probably because of prolonged summertime flood events associated with power generation at the Turners Falls dam.

One of the most important aspects of the habitat for plants on the Connecticut River is the highly variable flow regime. Several of the plants of conservation concern occur within the Connecticut because of the variation in flows. These include Mountain Alder, Tradescant's Aster, Sandbar Cherry, and Sandbar Willow. For these species, the scoured stone forming the channel and banks offers critical substrate, as do the cobble and sand point bar islands.

Although the Merrimack also has a variable flow regime, the dams have mitigated the flow regimes so that very few of the rare plants occur upstream of the dams. The rare plant species associated with the Merrimack are mostly associated with the tidal section of this river. This includes Eaton's Beggar-ticks and Estuary Arrow-head. Eaton's Beggar-ticks is a globally rare, slender, annual herb of the Merrimack. It is found growing on a narrow band of tidal muck along the river shore. The Estuary Arrowhead is restricted to sandy shores and mudflats of freshwater and brackish tidal rivers and marshes. The plants thrive with submergence under high-tide conditions and exposure during low tides.

Silverling, a low-growing perennial in the Carnation family (Caryophyllaceae) that forms broad tufts, is also found on the Merrimack River. In other states, Silverling grows in open areas in the crevices of granitic rock slopes and ledges and on gravelly soils that are poor in organic matter, usually at mid- to upper elevations in mountains. The sole Massachusetts site, a granite riverine island, is unique. Here, Silverling grows in the crevices and crags of granite ledges situated above the high-tide mark. It appears likely that this colony was established by seeds that floated down the Merrimack River.

In New England, Wright's Spike-sedge is known only from three rivers, the Connecticut, Merrimack, and Androscoggin. In Massachusetts, it is known only in the Connecticut, although populations of this species are known historically from the Merrimack River in New Hampshire, so there is potential that the species could be located on the Merrimack River within Massachusetts. The species prefers wet sand in non-tidal situations. Both of its Massachusetts populations occur in reaches of the river where there is less influence of the hydro-electric generating facilities, and in habitats that have more natural, run-of-the-river flows.

Tiny Cow-lily is one species that occurs in the backwaters associated with the Connecticut River mainstem, as well as in an oxbow of the Housatonic River. Like other members of the water-lily family, its leaves float on the surface of slow-moving or still waters. Although it was known historically from lakes and ponds in Massachusetts, only the riverine populations have been observed recently.

Table 4-4: Species of Greatest Conservation Need in the Connecticut and Merrimack Mainstems

Taxon Grouping	Scientific Name	Common Name
Fishes	*Acipenser brevirostrum*	Shortnose Sturgeon
	Acipenser oxyrinchus	Atlantic Sturgeon
	Alosa aestivalis	Blueback Herring
	Alosa pseudoharengus	Alewife
	Alosa sapidissima	American Shad
	Anguilla rostrata	American Eel
	Catostomus commersoni	White Sucker
	Hybognathus regius	Eastern Silvery Minnow
	Lota lota	Burbot
	Luxilus cornutus	Common Shiner
	Petromyzon marinus	Sea Lamprey
	Salmo salar	Atlantic Salmon
	Semotilus corporalis	Fallfish
Birds	*Haliaeetus leucocephalus*	Bald Eagle
	Riparia riparia	Bank Swallow
Mussels	*Alasmidonta undulata*	Triangle Floater
	Anodonta implicata	Alewife Floater
	Lampsilis cariosa	Yellow Lampmussel
	Lampsilis radiata	Eastern Lampmussel
	Leptodea ochracea	Tidewater Mucket
	Ligumia nasuta	Eastern Pondmussel
	Strophitus undulatus	Creeper
Odonates	*Gomphus fraternus*	Midland Clubtail
	Gomphus quadricolor	Rapids Clubtail
	Gomphus vastus	Cobra Clubtail
	Gomphus ventricosus	Skillet Clubtail
	Neurocordulia obsoleta	Umber Shadowdragon
	Neurocordulia yamaskanensis	Stygian Shadowdragon
	Stylurus amnicola	Riverine Clubtail
Beetles	*Cicindela marginipennis*	Cobblestone Tiger Beetle
	Cicindela puritana	Puritan Tiger Beetle
Plants	*Alnus viridis* ssp. *crispa*	Mountain Alder
	Bidens eatonii	Eaton's Beggar-ticks
	Eleocharis diandra	Wright's Spike-sedge
	Hypericum ascyron	Great St. John's-wort
	Nuphar microphylla	Tiny Cow-lily
	Paronychia argyrocoma	Silverling
	Prunus pumila var. *depressa*	Sandbar Cherry
	Sagittaria montevidensis ssp. *spongiosa*	Estuary Arrowhead
	Salix exigua ssp. *interior*	Sandbar Willow
	Symphyotrichum tradescantii	Tradescant's Aster

Threats to Connecticut and Merrimack Mainstem

IUCN Threat 1: Residential and Commercial Development
Habitat Loss and Fragmentation: Impoundment, filling of wetlands bordering the rivers, and urbanization of the river corridor lead to habitat loss and fragmentation. Disconnection of the rivers from their floodplains by channelization has lead to dramatic changes in habitat. Structures such as bridges and dams that eliminate tidal influence will likely have detrimental effects to Eaton's Beggar-ticks and Estuary Arrowhead by changing water salinities and nutrient cycling. In many places in the northeast, shoreline development, including docks and boat ramps, has impacted areas suitable for this rarity. In addition, an increase in sedimentation in these areas may also affect these species. Sedimentation may result from filling wetlands, and from anthropogenic activities such as construction and recreational boating that dislodge bottom and shoreline sediments into the water column, causing local erosion and sedimentation in quieter waters.

Both rivers also have cities constructed on their banks that now contain the channels and prevent natural channel meanders and floodplain formation. These highly maintained river banks offer little natural habitat for species that might potentially use lower gradient banks or newly formed channels. An additional threat to the rivers is the expansion (upstream or downstream) of these types of constrictions to their channels. As rivers flow through cities, there is often less shade from vegetation cooling the water and higher run-off from sun-heated impervious surfaces, which warms the water within the channels. The warmer river water is less hospitable to the aquatic life.

IUCN Threat 2: Agriculture and Aquaculture
Agricultural impacts on both rivers are likely related to non-point source pollution of nutrients, pesticides, and sediment, and will be addressed further under IUCN Threat 9: Pollution. Additional impacts may be caused through surface and groundwater withdrawal for agricultural purposes. These activities are regulated by the Massachusetts Department of Environmental Protection under the Wetlands Protection Act and the Water Management Act.

Tiny Cow-lily grows in Connecticut River backwaters that are surrounded by agricultural land. Depending on individual farmer's agriculture practices, changes including increases in fertilizer or a reduction of a buffer between the edge of the field and the backwater areas might result in inhospitable habitat for the species by creating an overgrowth of other aquatic plants or increasing invasive species.

Aquaculture is not a major threat to these mainstems.

IUCN Threat 3: Energy Production and Mining
Hydropower development can restrict or delay fish migration, increase predation, and subject fish to direct damage and stress. Dams block upstream migrations, which can cut off adult fish form their historical spawning grounds and severely curtail reproduction. Conversely, downstream-migrating fish may be entrained into the turbines and suffer injury or mortality.

Above both the Turners Falls dam and the Holyoke dam, the Connecticut River flow is controlled by the dam operators. Upstream of the Turners Falls dam, water levels can vary by as much as 10 feet on a daily basis, depending on energy demands and release of water from the Northfield Mountain pumped storage facility. This dramatic daily change in water levels during the summer months has a negative impact on rare dragonfly larvae eclosing on the river banks, which cannot move to higher ground as the water levels rise once they have started the emergence process. The wakes from recreational boating only magnify this effect of rising water level; washing away numerous dragonfly larvae during the process of emergence (see Threat 6, below).

On the Connecticut River, Atlantic Salmon once were native throughout the system, spawning in many tributaries in Connecticut, Massachusetts, Vermont, and New Hampshire. American Shad and Blueback Herring ranged upstream to Bellows Falls, Vermont (rkm 280). But the construction of the Holyoke Dam (rkm 139) and the Turners Falls Dam (rkm 198) in the late 18th century with inadequate fish passage severely depressed the Shad and Herring populations and led to the extirpation of the Atlantic Salmon. Anadromous fish restoration efforts still suffer from a lack of effective fish passage at the Turners Falls Dam, where the goal of passing 50% of the fish that pass Holyoke is never met; the facility struggles to pass 10%, and 3% is the norm.

Similarly, the construction of the Essex Dam in Lawrence and the Pawtucket Dam in Lowell in the early 19th century led to severely depressed populations of American Shad and River Herring and the extirpation of the Atlantic Salmon population in the Merrimack River as well. As for the Connecticut River, ineffective fish passage at the second dam (Pawtucket) continues to hinder anadromous fish restoration efforts.

During daily peaks of energy demand, the large upstream hydropower projects on the Connecticut River increase generation, creating artificial flow fluctuations, called hydropeaking. This alters the natural flow regime of rivers and has a negative effect on ecosystems and biodiversity (Young et al. 2011). These unnaturally rapid changes in flow fundamentally change the physical habitat of the river. Water depth, water velocity, and wetted area all change at every point in the river and can change the habitat from suitable to unsuitable (or vice versa) in a matter of minutes. This is particularly detrimental to organisms or life-history stages with limited mobility like benthic microorganisms and fish eggs or fry. As these projects come up for federal relicensing resource managers are calling for operations that minimize daily peaking operations and more closely follow the natural annual hydrograph.

Changes to the flow regime on the Connecticut River, where there is a large concentration of rare plant species below the Turners Falls dam, might dramatically impact the health of these populations. The occasional mid-summer flood caused by a hurricane is unlikely to have long-lasting impacts. However, irregular flood events during the growing season when the species are in bloom or early fruit may damage the populations of Tradescant's Aster, Mountain Alder, Sandbar Willow, and Sandbar Cherry. The flow regimes downstream of the Turners Falls dam have become more variable due to changes in the hydroelectric power generation upstream, both in Massachusetts and further upstream in Vermont and New Hampshire.

The use of river water for noncontact cooling of energy production facilities can lead to significant increases in water temperature as well as direct mortality of fish and fish larva that are entrained. The major source of heat to the Connecticut River, the Vermont Yankee nuclear power plant, located in Vernon, Vermont, shut down in January, 2015, and another major contributor, the coal-fired Mt. Tom generation facility in Holyoke, is scheduled for shutdown as well.

IUCN Threat 4: Transportation and Service Corridors
Many terrestrial and aquatic invasive plant species travel along the transportation and service corridors. Aquatic invasives come in on boats via these corridors. Where such primary corridors cross the Connecticut and Merrimack rivers, there is the potential for introducing new invasive species to these waterways. Plants that might be particularly susceptible include Tiny Cow-lily and Wright's Spike-sedge, both of which may be crowded or shaded by such invasive species.

IUCN Threat 5: Biological Resource Use
New regulations (January, 2015) now prohibit the harvest of any fish from the inland waters of the Commonwealth for commercial use, so there is very little threat to fish from biological resource use.

However, native invertebrates are not protected by hunting and fishing statutes in Massachusetts, and therefore the collection of invertebrates is not regulated if they do not fall under MESA protection. The extent of commercial collection of freshwater mussels and odonates in Massachusetts is not currently known, but does occur. State Wildlife Action Plan species, or MESA-listed species, are unlikely to be collected, and commercial collection is likely to impact mostly common species.

IUCN Threat 6: Human Intrusions and Disturbance
Recreational use of these rivers, whether by boat or on foot, can degrade habitat and sometimes cause outright destruction of these SGCN. Boat wakes on the Connecticut River can sometimes wash over large percentages of fragile emerging dragonflies and damselflies, causing damage or mortality. Picnickers, hikers, and other recreational users can trample the burrows of tiger beetles, causing the larvae to waste energy rebuilding their burrows more frequently than normal. Rare spike-sedges often occur in areas of low-gradient shores, which are preferred access points for recreational users. Nesting Bald Eagles can be disturbed and caused to abandon their nests by close human approach, even if inadvertent.

IUCN Threat 7: Natural System Modifications

Hydroelectric Dams: A recent compilation by the U.S. Army Corps of Engineers lists approximately 35,000 dams in the United States alone that are 25 feet high and impound an area of at least 15 acre-feet (USACE 2009). Dams convert river sections from lotic to lentic systems; inundate terrestrial landscapes; modify the export of water, sediment, and nutrients to downstream systems; alter fluvial thermal regimes; disconnect river segments from their floodplains, riparian zones, and adjacent wetlands; and change the overall physical, chemical, and biological structure and function of river systems. The Connecticut and Merrimack are some of the most developed rivers in the Northeast. The Massachusetts sections of each of these rivers contain two major hydroelectric dams, including the first dam upstream from the sea on each system. These large dams with operating hydroelectric facilities create unique threats to fish and wildlife populations:

- Impoundment: About one-third of the mainstem Connecticut River and most of the freshwater habitat of the Merrimack River in Massachusetts are impounded. The habitat found in these impoundments is far different from that in free-flowing rivers. In the impoundment a flowing river is transformed into a non-flowing pond and the species of fish, microorganisms, and aquatic plants found there are different (Baxter 1977). This created habitat is then often colonized by exotic and invasive species. Wright's Spike-sedge is only known from sections of the Connecticut River that are minimally impacted by the changed flow regime resulting from hydroelectric dams. The two known populations occur in reaches that are near the upper extent of impact from dam impoundments. Additional populations may have been present prior to the construction of such dams. Although it is impossible to say that these species no longer occur there due to the construction of the dams, a number of other rare plants were known from the Merrimack River historically, but can no longer be found.
- Bypass: Large hydroelectric projects were built at the sites of natural features conducive to water power, e.g., at natural falls. On the Connecticut River, the Hadley Falls and the Turners Falls are now the sites of major dams that divert much of the river flow away from the rapids habitat below. In fact, the former rapids below both the Turners Falls dam on the Connecticut and the Pawtucket dam on the Merrimack are dry for much of the summer. Because of the dams, the original rapids habitats of these very large rivers are now gone or radically altered, to the point that this kind of riverine habitat is essentially missing from Massachusetts. The water from the Turners Falls dam is returned after it has flowed through the Cabot Station hydro-electric stations downstream.
- Population fragmentation: Dams form barriers to migration, which can dramatically reduce the habitat available to anadromous fish and may fragment resident fish populations. This reduction in fish migration also affects freshwater mussels, whose larvae are parasitic on fish. Mussels can disperse over long distances only by means of their fish hosts.
- Flow alteration: The Turners Falls Hydroelectric Project on the Connecticut River is a "peaking" project. It stores water over a period of several hours, and then releases it as needed for power generation. The amount and timing of the releases vary from day to day and hour to hour. Sometimes, these releases dramatically change the river flow. These daily changes in flow below the dam and reservoir level above the dam disrupt fish and wildlife habitat and lead to large-scale riverbank erosion. Water level rises can occur quickly and have a dramatic and devastating impact on eclosing rare dragonflies, which have their highest population levels in the relatively undeveloped section of the Connecticut River upstream of the Turners Falls dam. The change in water levels is also a primary suspect in the erosion of riverbanks, both upstream of the dam, where the water levels can change up to 10 feet per day, and downstream, where water can be released or held by the dam at the whim of the operators within a range of parameters.

IUCN Threat 8: Invasive and Other Problematic Species and Genes

Invasive Species: A number of invasive species have taken hold in these watersheds and threaten native species. These include: Common Reed (*Phragmites australis*), Purple Loosestrife (*Lythrum salicaria*), Eurasian Milfoil (*Myriophyllum spicatum*), European Alder (*Alnus glutinosa*), and Water Chestnut (*Trapa natans*), as well as Mute Swans (*Cygnus olor*), Asiatic Clams (*Corbicula fluminea*), and Woolly Adelgid (*Adelges tsugae*). Fortunately, neither the Connecticut nor the Merrimack has yet been invaded by Zebra Mussels. The threat of these mussels is very real, however, as they have taken hold and become a major scourge in nearby waters, e.g., the Hudson River and Lake Champlain, where they have displaced local populations of native bivalves and fishes (Strayer et al. 2014 a, b).

The invasive exotic species Eurasian Water-milfoil, Curly-leaved Pondweed (*Potamogeton crispus*), Fanwort (*Cabomba caroliniana*), and Water-chestnut have been reported from the same sites as the remaining populations of Tiny Cow-lily, and may be competing with it for resources. Unfortunately, the use of broad-spectrum herbicides to control aquatic weeds could also threaten this rare species.

Within the estuary habitats where Eaton's Beggar-ticks and Estuary Arrowhead grow, invasive plants such as Purple Loosestrife and Common Reed threaten rare species by growing at densities capable of excluding other plants.

IUCN Threat 9: Pollution

Water Quality Threats: Threats include specific locations of problems such as toxins in the rivers (e.g., PCBs), combined sewer overflows (CSOs), bio-accumulation of contaminants, and non-point source pollution, such as agricultural runoff. One example was the presence of coal tar in the sediment of the Connecticut River. The former Gas Works in Holyoke manufactured combustible gas from coal and oil for residential, commercial, and industrial heating and lighting from 1852 to 1951. The former Gas Works once occupied a 2-acre peninsula on the Connecticut River, 1500 feet downstream of the Holyoke Dam. Historical operations resulted in large releases of tar and oil to soil, groundwater, sediment, and surface water.

Between 2002 and 2006, 11,714 cubic yards of tar and tarry sediment were removed. The removal was accomplished using mechanical excavation in dry (dewatered) areas and in wet excavations where dewatering was impractical or not feasible. The work was performed during summer and fall months to avoid critical fish life cycles, migratory periods, and dangerous high flow conditions. Mussel and fish relocation were conducted to reduce exposures in work areas. The NHESP provided oversight to a mussel removal and relocation program that resulted in the relocation of 26,000 mussels between 2002 and 2005. Additional studies of the river contamination are ongoing as overseen by the Massachusetts DEP.

The tar deposits exist in an area known to provide spawning habitat for the federally endangered Shortnose Sturgeon. Two state-listed mussel species, Tidewater Mucket and Yellow Lampmussel, as well as numerous finfish and common mussel species, inhabit the same stretch of river as the tar deposits.

There is a similar site on the Connecticut River in Springfield, where studies are underway to determine if a cap-in-place strategy rather than removal will eliminate the threat of contamination. This site could expose sturgeon (although it is not a spawning area) and mussels (but not state-listed species), as well as other fish, to these poisonous chemicals.

Combined Sewer Overflows (CSOs) in Massachusetts regularly cause temporary Class C water quality conditions in urban areas after storm events, an issue the Combined Sewer Overflow Control Policy (Notice, USEPA, Federal Register, April 19, 1994, at 59 Fed. Reg. 18688) is designed to address. The first milestone under the CSO Policy was the January 1, 1997, deadline for implementing minimum technology-based controls, the nine minimum controls, which are measures that can reduce the prevalence and impacts of CSOs and that are not expected to require significant engineering studies or major construction:

1. Proper operation and regular maintenance programs for the sewer system and the CSOs;
2. Maximum use of the collection system for storage;
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized;
4. Maximization of flow to the oublicly owned treatment works for treatment;
5. Prohibition of CSOs during dry weather;
6. Control of solid and floatable materials in CSOs;
7. Pollution prevention;
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts;
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

Communities with combined sewer systems are also expected to develop long-term CSO control plans that will ultimately provide for full compliance with the

Clean Water Act, including attainment of water quality standards.

Massachusetts still has CSO issues in major metropolitan areas along both the Merrimack (in Haverhill, Lawrence, and Lowell) and Connecticut (in Agawam, Chicopee, Ludlow, Holyoke, Montague, South Hadley, Springfield, and West Springfield) rivers. These CSO communities in Massachusetts are now in various stages of developing and implementing their long-term control plans, including characterizing their combined sewer systems; monitoring the impacts of CSOs on waterways; and discussing water quality and CSO control goals with permitting authorities, water quality standards authorities, and rate payers.

Air Pollution: Acid precipitation and atmospheric deposition of mercury and other contaminants continue to be a problem throughout the Northeast, despite recent clean-up efforts. While some sources are local, most sources of air pollution affecting our rivers are outside the region. For example, the Upper Merrimack watershed is highly impacted by acid precipitation. The soils have no buffering capacity left and the mobilization of aluminum during the spring snow melt has been hypothesized as a major determent to Atlantic Salmon in the system (Monette 2007; Monette et al. 2008).

IUCN Threat 10: Geological Events
These threats (volcanoes, earthquakes/tsunamis, avalanches/landslides) are relatively minor contributors to changes to the Connecticut and Merrimack mainstems over short time periods (up to a century). Occasionally, landslides of the river banks will occur, either because of natural meandering of the river course or because large and rapid releases from upstream dams accelerate such erosion events.

IUCN Threat 11: Climate Change and Severe Weather
Many of the rare plant species occurring on the Connecticut and Merrimack mainstems could be negatively impacted by both climate change and related severe weather events. Already, extreme precipitation events in the entire Connecticut River basin have increased by as much as 240% over the past 60 years (Parr and Wang 2014); these increases in precipitation will inevitably affect flows in the Connecticut River mainstem. Initially, the warmer conditions may make Massachusetts inhospitable for more northern species, such as Silverling, Mountain Alder, Tradescant's Aster, Eaton's Beggar-ticks, Wright's Spike-sedge, and Tiny Cow-lily. In addition, scouring resulting from severe weather, such as recently observed with the very high flows of Hurricane Irene and Superstorm Sandy, caused unusual erosion of riverbanks along both rivers, with large trees and their roots, soils, etc., being swept into the rivers and downstream. Areas that normally have low flows due to parallel bypass channels constructed for energy generation were suddenly inundated with large woody debris flowing over dams and lodging on sandbar islands and rocky points, scouring areas and breaking and removing established plants.

Conservation Actions for Connecticut and Merrimack Mainstems

Direct Management of Natural Resources
Pursue dam removal and fish passage projects to reconnect mainstem habitats to tributary habitats.

- Connecticut River and its tributaries: Look to install upstream passage for American eel wherever feasible. Continue to monitor the Holyoke fish lift, the Turners Falls fish ladders, and the West Springfield fishway on the Westfield River. Continue to monitor the Manhan River fishway (new in 2014). Continue to pursue dam removal and/or fish passage at the first three dams on the Green River. Continue to explore fish passage options for the Chicopee River. Continue active participation in the Connecticut River Atlantic Salmon Commission (CRASC). While the Atlantic salmon restoration program has ended on the Connecticut River, the CRASC continues to coordinate Connecticut River diadromous fish restoration efforts (American Eel, American Shad, Blueback Herring, Sea Lamprey, and Shortnose Sturgeon). Continue to support the targeted trap and transport program of both adult river herring and shad to selected tributaries.
- Merrimack River and its tributaries: Look to install upstream passage for American eel wherever feasible. Continue to monitor the fish lifts at Lawrence and Lowell as well as the ladder at Centennial Island on the Concord River. Continue to pursue dam removal and/or fish passage on the Nashua River. Continue to support the removal of the first two dams on the Shawsheen River. Continue to support the targeted trap and transport program of both adult river herring and shad to selected tributaries. Continue active participation in the Merrimack River diadromous fish restoration group to manage American Eel, American Shad, Blueback Herring, Sea Lamprey, and Shortnose Sturgeon.

Conduct surveys, monitoring and research on the effects of dam removal on rare species to inform management and prioritization of dam removal. While establishment of riverine connectivity and fish passage is undoubtedly an effective restoration tool, the effects of dam removals on local rare mussel populations may be detrimental (Sethi, et al. 2004; Gangloff 2013). The Massachusetts DFW is currently working with the Massachusetts Division of Ecological Restoration, The Nature Conservancy, UMass Boston, and other local watershed groups to assess how dam removal may affect invertebrate communities. This approach will help DFW to understand and produce best management practices, and prioritize dam removals to benefit both fish and freshwater mussels across the state.

Data Collection and Analysis
Investigate the effects of mainstem dams on resident fish populations.

Use the statewide freshwater mussel survey to assess communities and monitor populations within the Connecticut and Merrimack mainstems. Much of the freshwater mussel fauna of the Merrimack River has been undersurveyed in the past, and future surveys will better inform regulatory review and conservation actions within the mainstem of the river.

Continue to monitor rare plant populations to determine if and how they are being affected by activities on the river, and make recommendations to mitigate impacts.

Education and Outreach
Provide education to town conservation commissions to ensure proper enforcement and interpretation of the Wetlands Protection Act.

Educate the public and private sectors about the importance of the Connecticut and Merrimack rivers and how to protect them.

Harvest and Trade Management
Work with biological supply companies to determine methods, extent, and species collected for commercial purposes through voluntary reporting. Educate collectors on proper species identification.

Land and Water Rights Acquisition and Protection
Protect land along these rivers through land purchases or conservation easements. In Massachusetts, there are about 4538 acres of land within 100 meters of the Merrimack River, and about 5569 acres within 100 meters of the Connecticut River. For the Merrimack River, about 541 (or 12%) of those acres are permanently protected; for the Connecticut River, about 749 (or 13%) acres are permanently protected.

An additional 149 (3%) acres adjacent to the Merrimack and 534 (10%) acres near the Connecticut are under a state Agricultural Preservation Restriction (APR); these APRs prohibit future non-agricultural development (such as subdivisions), but do very little to protect water quality in the rivers, as often the land is cultivated right up to the river bank. Conversely, a minimum of 565 (10%) acres adjacent to the Connecticut River is developed; the corresponding figure for the Merrimack is 1,083 (24%) acres. The protection levels of the two rivers are quite different—true even for the different reaches within one river—with much more land protection and fewer anthropogenic features in the upper reaches of the Connecticut River.

Law Enforcement
Work with the Massachusetts DEP and the United States EPA to implement sound wastewater management and eliminate the known urban CSO problems.

Regulate and limit the impacts of development on stretches of the Connecticut and Merrimack rivers used by state-listed species.

Law and Policy
The highest priority conservation action for this SWAP Habitat is to work through the FERC relicensing process to mitigate the effects of hydroelectric dams. Specifically, relicensed projects should have adequate upstream and downstream fish passage and should operate as run-of-river (no peaking) to provide suitable habitat for fishes (Murchie et al. 2008) and invertebrates (Layzer and Madison 1995; Layzer and Scott 2006).

Planning
Develop detailed conservation and recovery plans for SGCN associated with the Connecticut and Merrimack mainstems. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these riverine SGCN populations.

Continue CRASC (Connecticut River Atlantic Salmon Commission), now concentrating on other diadromous fish in the river besides Atlantic Salmon, such as eels, herring, shad, and lamprey.

A similar diadromous fish group also exists for the Merrimack River.

Coordinate with the Silvio O. Conte National Wildlife Refuge on conservation planning efforts in the Connecticut River watershed in Massachusetts.

Species Reintroduction and Stocking
Continue the ongoing interagency anadromous fish restoration programs on both the Connecticut and Merrimack rivers. Investigate the feasibility of a freshwater mussel propagation facility and population augmentation of rare species within the mainstems of the Connecticut and Merrimack rivers. Freshwater mussel propagation, reintroduction, and population augmentation has proven an effective restoration tool in other regions (Bishop, et al. 2006; Haag 2012), and has been highlighted as an important goal for freshwater mollusk conservation throughout North America (Haag and Williams 2014; FMCS 2013).

Links to Additional Information

- Connecticut River Watershed 2003 Water Quality Assessment, from the Massachusetts Department of Environmental Protection
- Connecticut River 5-Year Watershed Action Plan: 2002-2007, from the Massachusetts Dept. of Environmental Management (now known as the Dept. of Conservation and Recreation)
- The Connecticut River Strategic Plan, Volume One, from the Pioneer Valley Planning Commission, West Springfield, Massachusetts
- Merrimack River Watershed 2004 Water Quality Assessment, from the Massachusetts Department of Environmental Protection
- Merrimack River 5-Year Watershed Action Plan: 2002-2007, from the Massachusetts Dept. of Environmental Management (now known as the Dept. of Conservation and Recreation)
- Connecticut River Watershed Council, a non-profit working to protect the entire Connecticut River watershed in four states
- Merrimack River Watershed Council, a non-profit working to protect the Merrimack River watershed
- American Shad Habitat Plan for the Connecticut River, from the Connecticut Department of Energy

and Environmental Protection, Division of Marine Fisheries; Massachusetts Divisions of Marine Fisheries and Fisheries and Wildlife; New Hampshire Fish and Game Department; and United States Fish and Wildlife Service

- *Freshwater Mussels and the Connecticut River Watershed*, by Ethan Nadeau, in cooperation with the Connecticut River Watershed Council
- Connecticut River Atlantic Salmon Commission, with federal, state, and public representatives from the entire watershed, coordinating on the restoration of migratory fish species in the Connecticut River basin
- Merrimack River Anadromous Fish Program, with federal, state, and public representatives from the entire watershed, coordinating on the restoration of migratory fish species in the Merrimack River basin

Large and Mid-sized Rivers

Habitat Description

In Massachusetts, large and mid-sized rivers constitute most of the mainstem rivers and their larger tributaries. The Connecticut and Merrimack mainstems are described in a separate habitat category. There are 32 major watershed basins in the state. These rivers, like the small streams that feed them, vary immensely, but some generalities apply. Gradient typically declines in these rivers from the higher gradient headwaters. Sediment sizes decrease and deposits of organically enriched soils deposit in greater amounts in widening floodplains. These rich floodplains are the foundation for productive floodplain forests, shrub swamps, and other habitats.

Large and mid-sized riverbeds shift and form braids and bend pools, as geology and gradient dictate. The rivers are typically not fully enclosed by tree canopies and begin to produce more of their energy through primary productivity. These changes in turn result in changes to the fauna that live within the habitat. The variability is probably best described by comparing the Taunton River to the Kinderhook River. The Taunton is a 48-mile river that drops only 20 feet along its mainstem, has large wetland areas, and is fed by more than 100 tributaries. The Kinderhook has only five river-miles in Massachusetts, is high-gradient, and has only six small tributaries. Watersheds like the Housatonic have limestone contributions that buffer them from the impacts of acid rain, while the Millers and Westfield watersheds are very low in limestone and are more susceptible to the impacts of acid deposition.

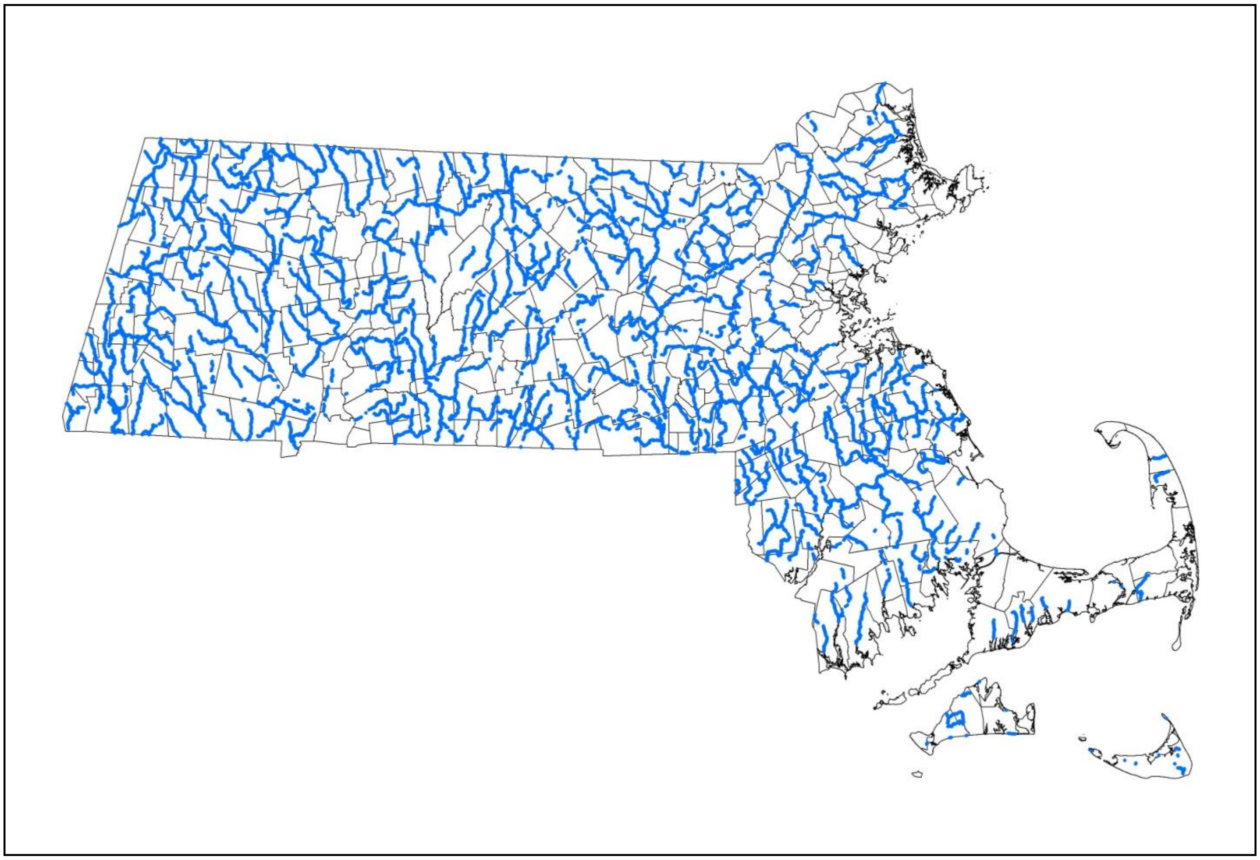


Figure 4-3: Large and Mid-sized Rivers in Massachusetts.

Data from MassGIS Major Streams datalayer.

Species of Greatest Conservation Need in Large and Mid-sized Rivers

Sixty-six SGCN are assigned to Large and Mid-sized Rivers (Table 4.5).

Most of the populations of Shortnose and Atlantic sturgeon in Massachusetts are found in the Connecticut and Merrimack river mainstems, covered elsewhere in this plan. However, these fish do (and did, historically, to a greater extent) use a few other large rivers in the state. Although classified as an anadromous fish, the Shortnose Sturgeon is almost never found in the open ocean. Instead, individuals spend their lives in the rivers, undergoing migrations between discrete spawning, rearing, and feeding areas, including in the estuary. Spawning occurs in the spring in rapidly moving sections of the mainstem rivers, now found only below dams. Atlantic Sturgeon are anadromous, entering large freshwater river systems to spawn during the spring. While there are no spawning populations of the Atlantic Sturgeon in Massachusetts, juvenile Atlantic Sturgeon can occasionally be found in the estuaries and lower portions of the major rivers during the summer months.

Lake Chubs and Longnose Suckers are found in cold, clear, fast-flowing rivers of the western third of the state. Lake Chubs are quite uncommon in the Westfield River, while Longnose Suckers are relatively more common, in the Westfield, Deerfield, Hoosic, and Housatonic drainages.

American Shad populations exist in many large to mid-sized coastal rivers, as well as in large to mid-sized tributaries of the Connecticut and Merrimack rivers. American Shad are anadromous, migrating from the ocean to freshwater specifically to reproduce. Adult shad enter rivers in the spring, mid-April through June. Spawning occurs in the mainstem rivers and their larger tributaries in the early summer. Spawning usually occurs over gently sloping areas with fine gravel or sandy bottoms. After spawning, adult shad return to the sea. Fertilized eggs are carried by river currents and hatch within a few days. Larvae drift with the current until they mature into juveniles, which remain in nursery areas (mainstem rivers and their larger tributaries), feeding on zooplankton and terrestrial insects. By late fall, most juvenile shad migrate to near-shore coastal wintering areas. Some juvenile shad will remain in mainstem rivers and estuaries up to a year before entering the ocean.

River herring (Alewife and Blueback Herring) populations exist in many large to mid-sized coastal rivers, as well as in large to mid-sized tributaries of the Connecticut and Merrimack rivers. River herring spawn in mainstem rivers and tributaries from April to mid-July, when water temperatures range from 51° (Alewife) or 57° (Blueback Herring) to 81° F. Upstream distribution of adults is a function of habitat suitability and hydrologic conditions permitting access to these sites. Immediately after spawning, surviving adult river herring migrate rapidly downstream to return to the sea. Alewives are still-water spawners and focus their reproductive efforts in the tidal portions of the rivers. In addition to the mainstem, Alewives also use spawning habitat in backwaters and impoundments. Spawning can occur over a range of substrates, such as gravel, sand, detritus, and submerged vegetation.

Blueback Herring spawning sites include swift-flowing sections of freshwater rivers, channel sections of fresh and brackish tidal rivers, and coastal ponds over gravel and clean sand substrates. Blueback Herring often migrate farther upstream than do Alewives. Juvenile river herring occur in non-tidal and tidal freshwater and semi-brackish areas (mainstems and major tributaries) during spring and early summer, moving upstream during periods of decreased flows and encroachment of saline waters. Juveniles begin migrating from their nursery areas to the sea in the fall, cued by heavy rainfalls, high waters, or sharp declines in water temperatures.

The American Eel is a catadromous species that spends most of its life in rivers, lakes, and estuaries, but migrates to the ocean to spawn. Populations of American Eel occur in many large to mid-sized coastal rivers, as well as in large to mid-sized tributaries of the Connecticut and Merrimack rivers. Some eels remain in the estuaries, but others migrate varying distances upstream, often for several hundred kilometers. American Eels will remain in the brackish and fresh waters of these rivers for the majority of their lives, for at least 5 and possibly as many as 20y years. Mature eels migrate back to the waters of the Sargasso Sea to spawn. The migration occurs throughout autumn nights, with adults descending streams and rivers to the estuaries for January spawning in the warm Caribbean waters.

Slow-moving, low-gradient rivers, particularly those with shrubby or wooded areas adjacent, support Wood Turtles across much of Massachusetts. While most nesting pairs of Bald Eagles are on the mainstems of the Connecticut and Merrimack rivers, nesting adults, as well as summering immatures and wintering or migrating eagles of all ages, use the state's large to mid-sized rivers for feeding.

Slender Walker is found in one small section of a smaller river in the western part of the state. Nine rare freshwater mussels inhabit large to mid-sized rivers, most notably the federally Endangered Dwarf Wedgemussel, found only in tributaries to the Connecticut River. Thirteen species of rare dragonflies use a range of riverine habitats in Massachusetts, but many are found only in clear, swiftly flowing, and relatively clean rivers over gravel, cobble, or rocky substrates. The Twelve-spotted Tiger Beetle inhabits silt and clay deposits along rivers in western Massachusetts.

Eaton's Beggar-ticks, Long's Bitter-cress, and Parker's Pipewort are only associated with freshwater tidal rivers. Estuary Beggar-ticks is confined to the higher saline stretches of these rivers and their associated salt marshes. Shore Pygmyweed and American Waterwort may be found in tidal rivers as well, but also may be found on inland river banks. Mountain Alder is a specialist on the rocky outcrops and shores of northwestern Massachusetts mid-sized rivers and streams. Sandbar Cherry, Matted Spike-sedge, Ovate Spike-sedge, Frank's Lovegrass, Shore Sedge, and Great St. John's-wort may be found on sandbars and sandy-gravelly shores of inland rivers. Round-fruited Seedbox, Tiny Cow-lily, Budding Pondweed, and Wapato inhabit the river backwaters or slow-moving waters of large rivers.

Table 4-5: Species of Greatest Conservation Need in Large and Mid-sized Rivers

Taxon Grouping	Scientific Name	Common Name
Fishes	*Acipenser brevirostrum*	Shortnose Sturgeon
	Acipenser oxyrinchus	Atlantic Sturgeon
	Alosa aestivalis	Blueback Herring
	Alosa pseudoharengus	Alewife
	Alosa sapidissima	American Shad
	Anguilla rostrata	American Eel
	Catostomus catostomus	Longnose Sucker
	Catostomus commersoni	White Sucker
	Couesius plumbeus	Lake Chub
	Enneacanthus obesus	Banded Sunfish
	Erimyzon oblongus	Creek Chubsucker
	Etheostoma fusiforme	Swamp Darter
	Etheostoma olmstedi	Tessellated Darter
	Hybognathus regius	Eastern Silvery Minnow
	Lota lota	Burbot
	Luxilus cornutus	Common Shiner
	Notropis bifrenatus	Bridle Shiner
	Petromyzon marinus	Sea Lamprey
	Rhinichthys atratulus	Blacknose Dace
	Rhinichthys cataractae	Longnose Dace
	Salmo salar	Atlantic Salmon
	Salvelinus fontinalis	Brook Trout
	Semotilus atromaculatus	Creek Chub
	Semotilus corporalis	Fallfish
Reptiles	*Glyptemys insculpta*	Wood Turtle
Birds	*Haliaeetus leucocephalus*	Bald Eagle
	Riparia riparia	Bank Swallow
Snails	*Pomatiopsis lapidaria*	Slender Walker
Mussels	*Alasmidonta heterodon*	Dwarf Wedgemussel
	Alasmidonta undulata	Triangle Floater
	Alasmidonta varicosa	Brook Floater
	Anodonta implicata	Alewife Floater
	Lampsilis cariosa	Yellow Lampmussel
	Leptodea ochracea	Tidewater Mucket
	Ligumia nasuta	Eastern Pondmussel
	Margaritifera margaritifera	Eastern Pearlshell
	Strophitus undulatus	Creeper
Odonates	*Boyeria grafiana*	Ocellated Darner
	Gomphus abbreviatus	Spine-Crowned Clubtail
	Gomphus descriptus	Harpoon Clubtail
	Gomphus fraternus	Midland Clubtail
	Gomphus quadricolor	Rapids Clubtail
	Gomphus ventricosus	Skillet Clubtail
	Neurocordulia obsoleta	Umber Shadowdragon
	Neurocordulia yamaskanensis	Stygian Shadowdragon
	Ophiogomphus aspersus	Brook Snaketail
	Ophiogomphus carolus	Riffle Snaketail
	Stylurus amnicola	Riverine Clubtail
Beetles	*Cicindela duodecimguttata*	Twelve-Spotted Tiger Beetle
Plants	*Alnus viridis* ssp. *crispa*	Mountain Alder
	Bidens eatonii	Eaton's Beggar-ticks
	Bidens hyperborea	Estuary Beggar-ticks
	Cardamine longii	Long's Bittercress

Taxon Grouping	Scientific Name	Common Name
	Carex lenticularis	Shore Sedge
	Crassula aquatica	Shore Pygmy-weed
	Elatine americana	American Waterwort
	Eleocharis intermedia	Matted Spike-sedge
	Eleocharis ovata	Ovate Spike-sedge
	Eragrostis frankii	Frank's Lovegrass
	Eriocaulon parkeri	Parker's Pipewort
	Hypericum ascyron	Great St. John's-wort
	Ludwigia sphaerocarpa	Round-fruited Seedbox
	Nuphar microphylla	Tiny Cow-lily
	Potamogeton gemmiparus	Budding Pondweed
	Prunus pumila var. *depressa*	Sandbar Cherry
	Sagittaria cuneata	Wapato

Threats to Large and Mid-sized Rivers

Threats to large and mid-sized rivers come in two broad categories: 1) those inherited from small streams; and 2) those directly impacting the river or surrounding watershed area. Although the threats to small streams are described in that habitat summary, it bears mentioning that many threats facing large and mid-sized rivers can be alleviated through restoration in the small streams (Person 1936). Threats to large and mid-sized rivers result in reductions to the physical habitat, water quality, and/or water quantity available for the Species in Greatest Need of Conservation. Watershed Assessment Reports, published by the Massachusetts DEP, are available for these habitats at http://www.mass.gov/dep/brp/wm/wqassess.htm.

There is a great degree of variability in the threats facing the 27 major watersheds in Massachusetts. The riverine components (hydrology, geomorphology, biology, water chemistry, and connectivity; Annear et al. 2004) of all major basins in Massachusetts have been altered to some extent both temporally and spatially. The degradations of these components lead to alterations to the five elements of the natural flow regime (magnitude, frequency, duration, timing, and rate of change). Natural freshwater ecosystems are strongly influenced by specific facets of natural hydrological variability (Richter et al. 2003). Modification of flow thus has cascading effects on the ecological integrity of rivers (Poff et al. 1997). Some of the major perturbations, and the watersheds most impacted, are as follows:

IUCN Threat 1: Residential and Commercial Development

Residential and commercial development adjacent to waterbodies threatens aquatic habitats by altering water quality and physical habitat necessary to support aquatic flora and fauna. Increased impervious surface in the watershed, particularly adjacent to the waterbody, has been correlated to changes in hydrologic functioning, reduced water quality, increased nutrient loading and sedimentation, increased salinization, changes in surface water temperatures, and changes in fish community structure (Armstrong et al. 2011).

IUCN Threat 2: Agriculture and Aquaculture

The greatest threat that agriculture in general may pose to aquatic habitats is nutrient, pesticide and sediment pollution from runoff, which is assessed below under IUCN Threat 9: Pollution. Livestock farming also may pose an increased risk to rivers and streams where livestock are allowed to graze up to and across lotic systems, resulting in reduction of bank stability and direct contamination of the waterbody from animal waste. Storage of manure within the floodplain can result in washing of animal waste into streams during flooding events. Acute decreases in dissolved oxygen and increases in ammonia from such events have caused localized mussel kills, particularly in habitat of the federally threatened Dwarf Wedgemussel (*Alasmidonta heterodon*). Aquaculture operations can facilitate the transport of exotic organisms, parasites, and diseases into aquatic ecosystems, putting SWAP species at risk; however, aquaculture is minimal in the state and strictly regulated where it exists.

IUCN Threat 3: Energy Production and Mining
Dams on these rivers cause impacts to all watersheds in the state. The only mainstem considered to be free-flowing in the state is the Taunton River. In addition to currently inactive dams constructed during the last 300 years, there are also active dams that create impoundments for flood protection, industry (including cooling water and hydroelectric generation), and water supply. The Deerfield, Westfield, and Swift rivers have the majority of hydroelectric generation (excluding the Connecticut and Merrimack river mainstems, discussed elsewhere). Large-scale flood control projects exist on the Quinebaug, Westfield, and Millers rivers. Water supply reservoirs are common statewide and range in size from the 25,000-acre Quabbin Reservoir to smaller secondary or backup water supply impoundments. These dams all result in a loss of physical habitat suitable for fluvial species within the impoundment, but other habitat impacts are also apparent. Stream flow downstream of almost all impoundments is severely restricted during low-flow times of the year or when lakes are being refilled after an artificially induced lake drawdown. Minimum streamflow criteria are not regulated for most reservoir situations. Likewise, maximum streamflow is not regulated during artificial drawdowns when spring-like (or greater) flows are allowed to take place in times other than spring. These dams also cause a buildup of sediment, sometimes severely contaminated, within the impoundment which results in incised channels downstream of the impoundment. Incised channels further isolate the river channel from the surrounding floodplain.

The extent of gravel mining and quarrying in rivers and streams is currently minimal, but DFW's NHESP has reviewed proposed operations in MESA species habitat. Streambed quarrying will result in immediate harm to SWAP species, and both acute and long-term habitat degradation. Quarrying and mining in the uplands of a watershed may also increase heavy metal contamination in aquatic habitats and alter stream chemistry.

IUCN Threat 4: Transportation and Service Corridors
Road development has had legacy impacts on rivers and streams throughout the Commonwealth. Streams and rivers have been channelized to protect roads, and stream banks are armored in efforts to minimize bank erosion and migration toward infrastructure. Channelization and hardening of stream banks alters the hydrology and geomorphology of the river, and can reduce the creation of habitat utilized by aquatic invertebrates. Stream crossings, such as bridges and culverts, are often undersized for the size of the stream and result in impounding of water and sediments upstream of the crossing, and may limit habitat connectivity and passage of fish and other aquatic fauna. Increased impervious surface has been correlated to increased salinization, turbidity, and temperature changes in surface water, as well as increases in hydrologic variability (i.e., flashiness). Combined results of these impacts may result in localized or watershed-scale reductions in available habitat for fish, mussels, and other aquatic fauna.

Between 1990 and 2011, there has been a dramatic increase in road salt usage throughout the northern United States. Average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization. Chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into adjacent wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations (Corsi et al. 2015).

IUCN Threat 5: Biological Resource Use
The extent of harvesting of freshwater mussels and odonates in Massachusetts is not well known; however, commercial biological supply operations are known to be collecting freshwater mussels for educational supply, and odonates for educational supply and purported mosquito control. Collection of freshwater mussels for bait is also known to occur, but is not likely an extensive threat to an individual species. There is currently no jurisdictional protection of non-MESA-listed invertebrates in Massachusetts, and the effect on fauna may be minimal and localized. Some SWAP fish species are subject to exploitation through harvest for consumption or use as bait species. Both potential exploitation vectors are highly regulated.

IUCN Threat 6: Human Intrusions and Disturbance
Docks and boat ramps have impacted some of the habitat for several of the shoreline plant SGCN. Eaton’s Beggar-ticks, in particular, may be affected by storage of floating docks, in some years.

IUCN Threat 7: Natural System Modifications
Physical Habitat Alterations: Channelization, particularly near urban centers, has resulted in massive

habitat loss in all watersheds, but especially in the Charles, Concord, Blackstone, North and South Coastal, and Merrimack watersheds. Portions of some rivers, e.g., the Hoosic River in Adams and North Adams, have actually been completely culverted and run through flood chutes instead of natural channels.

Large dams affect SWAP species by altering habitat both below and upstream of the dam, and by limiting the hydrologic connectivity of the river. Impoundments upstream of the dam operate as lacustrine systems and have altered sediment, hydrology, and temperature regimes that are not conducive to riverine species. River reaches downstream of the dam are often sediment-starved and become incised as the river cuts into its bed rather than spilling out onto its floodplain. Particularly for large hydroelectric dams operating as peaking operations, the reach of river immediately downstream of the dam and bypassed reaches have hydrologic fluctuations at a periodicity that does not favor SWAP species that have evolved to tolerate environmental flows that vary by season (Hardison and Layzer 2001). Rapid changes in temperature are also associated with peaking operations and may disrupt one or more critical components in the invertebrate lifecycle (e.g., growth, reproduction, maturation: Gates et al. 2015, Galbraith et al. 2012, Maloney et al. 2012). Chronic temperature impacts are also common and due to the exposure of impounded water to direct solar radiation.

Dams of any size may reduce the dispersal of mussel glochidia on their fish hosts. Even large dams with well-designed fish passages are not suitable for passing most SWAP species. Host fish of some of Massachusetts' rarest unionids (i.e., Dwarf Wedgemussel and Brook Floater) are minnows and/or darters, which are not known to utilize fish ladders and lifts. Other species of mussel utilize diadromous fishes (e.g., Tidewater Mucket, Alewife Floater), and may be limited in their distribution because their host fish (e.g., white bass and river herring, respectively) are not provided adequate passage across dams (Nedeau 2008).

Dam removal is becoming an increasingly popular tool for the restoration of stream connectivity, in-stream habitat, and fish passage. While the benefit of dam removal to the function of riverine ecosystems has been well documented, the short-term threats to rare aquatic organism habitat are not always considered. Removal of dams without properly identifying adequate habitat for translocation and monitoring will result in significant losses to the population, including possible extirpation from that site (Sethi et al. 2004).

Surface water withdrawal for domestic, commercial and agricultural purposes reduces the available water within the aquatic habitat of SWAP species. Loss of water quantity can result in loss of aquatic habitat through drying and reduction in aquatic plants, and will also increase surface water temperatures, leading to further water quality concerns (e.g., increased risk of algal blooms, decreased dissolved oxygen, or physiological stress on aquatic species).

Annual drawdowns are a form of surface water withdrawal from lakes and ponds for management of nuisance aquatic vegetation. In Massachusetts, winter drawdowns of less than 3 feet serve for adequate protection and management of littoral vegetation, and are considered protective of fish and aquatic invertebrates when specific guidelines are met (Mattson et al. 2004). Following winter drawdown, refill of the reservoir in the spring represents an additional water withdrawal to the receiving waters below the reservoir. This is particularly concerning as stream flows in New England typically reach their highest sustained levels in the spring, thus most native fauna have adapted to this hydrologic cycle. When winter snowfall is inadequate to recharge the reservoir and groundwater during spring refill, reductions in flow below the reservoir may be significant and affect lifecycle processes of organisms below the dam. In particular, anodontine freshwater mussels (including MESA-listed Dwarf Wedgemussel, Brook Floater, and Creeper) are known to release glochidia in the spring (Nedeau 2008). Reduced spring flows from refill in upstream reservoirs may affect the ability of these mussels to infect host fish and limit recruitment classes. Continued effort is needed to assess environmental flows in receiving waters below reservoirs, lakes, and ponds with deeper drawdowns.

Groundwater withdrawal for agricultural, domestic, and commercial purposes has the potential to affect surface water volume and temperatures in all aquatic habitats. In particular, these events are exacerbated during droughts where surface water and groundwaters are not recharged from rainfall. Further reductions in groundwater inputs can result in dewatering of the river, leading to loss of habitat and changes in physical and chemical water quality parameters to levels unsupportive of native aquatic fauna (e.g., increased temperature, reduced dissolved oxygen, increased salinity).

IUCN Threat 8: Invasive and Other Problematic Species and Genes

The Asiatic Clam (*Corbicula fluminea*) has been increasing in distribution in Massachusetts waters, possibly through introduction by recreational boats. While potential threats posed to native bivalves have been identified (Vaughn and Spooner 2006), we are currently unaware of convincing documented evidence that Corbicula pose a significant risk to native unionids. Zebra Mussels (*Dresseina polymorpha*) are established in Laurel Lake (Lee, Massachusetts) and have been found within the Housatonic River downstream of the lake. Zebra Mussels pose significant threats to native unionids when conditions are favorable for expansion (Strayer 2007). Other Massachusetts state agencies (Dept. of Conservation and Recreation) have coordinated a risk assessment of Zebra Mussel invasion through other waterbodies in the state (Nedeau 2010). The water conditions throughout much of the central and eastern parts of Massachusetts are not predicted to be favorable for Zebra Mussel expansion. Nevertheless, continued cooperation with other agencies and occurrence tracking is warranted for these and other introduced aquatic species (e.g., Spiny Waterflea, *Bythotrephes longimanus*; Rusty Crayfish, *Orconectes rusticus*; Robust Crayfish, *Cambarus robustus*).

Common Reed (*Phragmites australis*), Purple Loosestrife (*Lythrum salicaria*), and Japanese Knotweed (*Fallopia japonica*) have all become problem species on the shores of the large and mid-sized rivers, shading the existing vegetation and destabilizing the banks. These species are regularly found on sandbars supporting Giant St. John's-wort. Flowering-rush (*Butomus umbellatus*) has been observed on the Saugus River, and if allowed to spread could become a problem, shading out existing vegetation. These invasive species are a primary threat to the plant SWAP species.

Beaver play an important role in lotic ecosystems and wetland creation in the state. In a few known locations of particularly imperiled mussel species, native environmental engineers like beavers can also pose threats to rare species. North American Beaver (*Castor canadensis*) are nearly fully restored and abundant on the Massachusetts landscape since their extirpation in the 1700-1800s. Where sympatric with Dwarf Wedgemussel and Brook Floater populations, beaver have had a significant yet localized effect on the habitat of these species (Nedeau 2009; David McLain field notes, NHESP database). Because of the limited number of populations of these mussels in the state, localized control of beaver populations and water management should be considered as part of site-specific habitat management plans.

IUCN Threat 9: Pollution

Sewage Treatment Effluent: Many of Massachusetts' large to mid-sized rivers are impacted by effluent from centralized sewage treatment plants. In some cases, raw sewage continues to be released into our waters. The Blackstone, Charles, Concord, and Nashua Rivers are particularly impacted. During summer low flows, the Blackstone and Assabet rivers are composed primarily of sewage treatment effluent.

Stormwater runoff has caused substantial changes to water quality and causes erosion issues. Winter runoff often includes high concentrations of road salt, while stormwater flows in the summer cause thermal stress and bring high concentrations of other pollutants. Roads, culverts, public water lines, and sewer lines have created pathways, both intentional (CSO flows) and unintentional (inflow and infiltration), that have expedited the movement of rainfall and runoff into stream channels.

Acidification of waterbodies from atmospheric deposition , while now considered not as much a threat as was previously thought, is still of concern throughout the northeastern United States. Alteration of the pH of a waterbody can reduce habitat suitability for sensitive native species. Further, the addition of nutrients from atmospheric deposition (e.g., nitrogen deposition) may also accelerate the effects of eutrophication and change in ecological function of waterbodies in Massachusetts.

IUCN Threat 10: Geological Events

Geological events are not a significant threat to large and mid-sized rivers in Massachusetts.

IUCN Threat 11: Climate Change and Severe Weather

Changes in climate and local weather patterns will likely affect aquatic systems by exacerbating or accelerating habitat degradation due to other identified threats. Increased periodicity and intensity of drought may cause loss of aquatic habitat through short-term drying, but may also concentrate effects of pollutants. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms.

Severe storms, such as Superstorm Sandy, can cause scouring and/or sedimentation of river banks, impacting SWAP plants on shorelines and sandbars. There is a potential for species located in backwaters to be impacted by high flows and washed from their habitat.

Conservation Actions

Direct Management of Natural Resources
Coordinate with non-profits, educational institutions, the USFWS, municipalities, and landowners to minimize the threat of agricultural animal waste in habitat of SWAP species. Approaches include restoration of riparian buffers and limiting access of livestock to streams.

Identify dam removal as a primary restoration tool and encouraging dam removal where appropriate.

Work with the Massachusetts Department of Transportation, other state agencies involved in habitat restoration, institutions of higher education, and non-profit organizations to identify and remediate stream crossings to restore connectivity of habitat.

Develop and carry out site-specific management plans to reduce extent and frequency of beaver impoundments in habitat of Dwarf Wedgemussel, Brook Floater, and Bog Turtle. Reassess feasibility and effectiveness of management plan every 5 years in sequence with freshwater mussel rotational monitoring.

Data Collection and Analysis
Conduct research into determining the priorities for restoration of these habitats by examining, in each watershed, the relative impacts caused by the threats listed above (the Meso-Habitat Simulation Model (MesoHabSim)). Work with other stakeholders and research agencies to create habitat suitability indices for aquatic invertebrate fauna to better inform the instream flow needs of rare mussels and odonates in regulated rivers.

Coordinate with the Massachusetts DEP, and conduct in-house monitoring of water quality in SWAP species habitat.

Surface water and groundwater withdrawals need more research and monitoring on the effects of these actions on water quality in rare species habitat.

Continue collaboration with USGS Massachusetts Cooperative Fisheries and Wildlife Research Unit to assess the ecological effects of drawdowns on aquatic fauna. Use research to define science-based management policies on extent and periodicity of drawdowns in habitats of SWAP species.

Develop and carry out monitoring and de novo sampling of freshwater mussel and odonate communities throughout the state on a 5-year rotation, where each DFW district is targeted per year. Sites or populations of immediate importance may necessitate deviation from the rotation when immediate threats or need to update information is apparent.

Continue to monitor and complete de novo sampling of SWAP plants associated with this habitat.

Work with other Northeastern states to develop standardized freshwater mussel population assessment approaches based on previously published methodologies and data reporting to better understand the regionwide threats to mussel conservation.

State agencies, The Nature Conservancy, and other interested stakeholders should continue to prioritize dam removals in sites where MESA-listed species will not be affected. Coordinate and conduct research into the effects of translocation on rare mussel fauna, to help develop dam removal best management practices in habitats of rare mussels and assess the risks and benefits to MESA-listed species.

Continue to track occurrences of invasive invertebrates during native species surveys. Encourage data reporting from other agencies, consultants, and academics.

Education and Outreach
Educate and inform the public about the values of large and mid-sized rivers and the issues related to their conservation, through agency publications and other forms of public outreach, in order to instill public appreciation and understanding.

Invasive Species: Devise educational material on the importance of proper identification and the potential problems with unintentional or illegal introductions.

Coordinate with town conservation commissions, Massachusetts DEP, and the Massachusetts Lake and Pond Advisory Committee to develop better avenues for reporting of drawdown metrics.

Collaborate with other state agencies toward information sharing and strategic planning on invasive species prevention and control. Work with other state agencies to define invasives of greatest risk, and collaborate as needed to find funding for research and conservation action for species that pose greatest threat.

Harvest and Trade Management
Identify commercial suppliers and request voluntary information on the species collected and collection sites. Continue to monitor the effectiveness of the existing regulatory framework for protecting SWAP fish species.

Land and Water Rights Acquisition and Protection
Collaborate with other conservation groups for targeted land protection in areas to improve habitat for MESA and SWAP species.

Law Enforcement
Provide education to town conservation commissions to ensure proper enforcement and interpretation of the Wetlands Protection Act and the related Rivers Protection Act.

Law and Policy
DFW will continue to review development projects within Priority Habitat of MESA-listed species.

DFW continues to review aquaculture regulations and work with enforcement agencies to ensure that the risks associated with the operation of aquaculture facilities minimizes risks to SWAP species.

Work with state and federal agencies to review and minimize the effects of current hydropower projects and future hydropower development on aquatic species through the Federal Energy Regulatory Commission (FERC) licensing process and the MESA and WPA project review processes. Continue to work within the FERC relicensing process and reviews under MESA and WPA to coordinate instream flows supportive of native aquatic fauna.

Provide methods for using biocriteria (Target Fish Communities) in water quality and quantity standards in Massachusetts.

Coordinate with municipalities and Massachusetts DEP to ensure surface and groundwater withdrawals are within the guidelines of the revised Water Management Act and the WPA.

Coordinate with MA DCR to include new invasive species on formal list of Aquatic Invasive Species for regulatory inclusion under the Act to Protect Lakes and Ponds and MA DCR regulations under the Aquatic Nuisance Control Program (302 CMR 18.00).

Planning
Develop detailed conservation and recovery plans for SGCN associated with large and mid-sized rivers. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these riverine SGCN populations.

Species Reintroduction and Stocking
Population restoration and augmentation of the rarest mussel species may be necessary where habitat is otherwise suitable. Collaborate with other Northeastern states, federal agencies, and academic institutions to assess the feasibility of a freshwater mussel propagation facility in New England. Provide technical expertise, research, and conservation direction to the development of restoration and reintroduction methods for freshwater mussels, including identification of refuge habitat for the most

critically imperiled species (Dwarf Wedgemussel and Brook Floater).

Population restoration and augmentation may also be needed for some of the rarest plant species. Additional appropriate habitats which are less impacted by anthropogenic activities should be located for these species, with a thought toward relocation and/or introduction in areas which will receive the appropriate management.

Marine and Estuarine Habitats

Habitat Description

Seaward of the sandy beaches and rocky coastlines, beyond the salt bays and estuaries, Massachusetts' territorial waters extend 3 nautical miles out into the Gulf of Maine (see Figure 4-4). The land under this area of open ocean is the relatively shallow continental shelf. Depths of seawater can range from 100 feet or so to a little more than 1,000 feet, but there are no deep trenches in Massachusetts waters. Almost all of Massachusetts salt waters are in estuaries and bays; very little, mostly the water east of the outer arm of Cape Cod, is open ocean.

A coastal bay is a large body of water partially enclosed by land but with a wide outlet to the ocean. Massachusetts has three great bays: Massachusetts Bay includes the area between Gloucester, on the south side of Cape Ann, to Brant Rock, north of Plymouth, where the Commonwealth's second great bay, Cape Cod Bay, begins. Cape Cod Bay includes the area from Plymouth to the tip of Cape Cod. The third great bay is Buzzards Bay on the south side of Massachusetts, extending from the Westport River near the Rhode Island border, east to the Cape Cod Canal and south to the last of the Elizabeth Islands. Within the great bays are smaller bays such as Nahant Bay north of Boston and the Hull, Hingham, and Quincy bays south of Boston, all within the area designated Massachusetts Bay. Buzzards Bay likewise has smaller named bays within its confines.

There are separate small bays as well, though the designation between bays, coves, and harbors is sometimes blurred. Ipswich Bay and Essex Bay are located on the north side of Cape Ann; Duxbury, Kingston, and Plymouth bays at the juncture of Massachusetts and Cape Cod bays; Pleasant Bay is found on the ocean side of outer Cape Cod; and a series of small bays are located on the south side of Cape Cod. Martha's Vineyard has its own small bays, though on Nantucket Island the Madaket area is referred to as a harbor.

Estuaries occur where freshwater rivers and streams reach the saltwater areas of the coast. Estuaries are affected by tidal flows and are considered brackish water. The degree of salinity of estuaries varies along the length of the estuary and with tidal ebb and flow. Estuaries often have associated saltmarsh habitat and are rich in nutrients, providing a valuable nursery for finfish, shellfish, and other macro- and microinvertebrates, and support a wide range of vertebrate wildlife. Estuaries are vital links in the life history of diadromous fishes (species that spend a portion of their lives in freshwater and a portion in the sea). Diadromous fishes do not simply migrate through these areas; rather, they rely on these complex ecosystems to provide food and protection while the physiological changes required to transition from life in freshwater to the sea (or vice versa) occur. The physical, chemical, and biological conditions present in the estuary are critical factors in this transition.

There are estuaries all along coastal Massachusetts, but the most extensive system lies just west of Plum Island at the mouth of the Merrimack River, feeding into Plum Island sound and the marshes of Essex County, with a small subsystem along the Annisquam River on the north side of Cape Ann. A second extensive estuary system is found in the Nauset Marsh/Pleasant Bay area on outer Cape Cod. Numerous shorter estuaries are found along the south side of Cape Cod. The East Branch of the Westport River is one of the longest estuaries in the Commonwealth draining into Buzzards Bay. The Taunton River has an extensive estuary that flows into Mount Hope Bay and Narragansett Bay in Rhode Island.

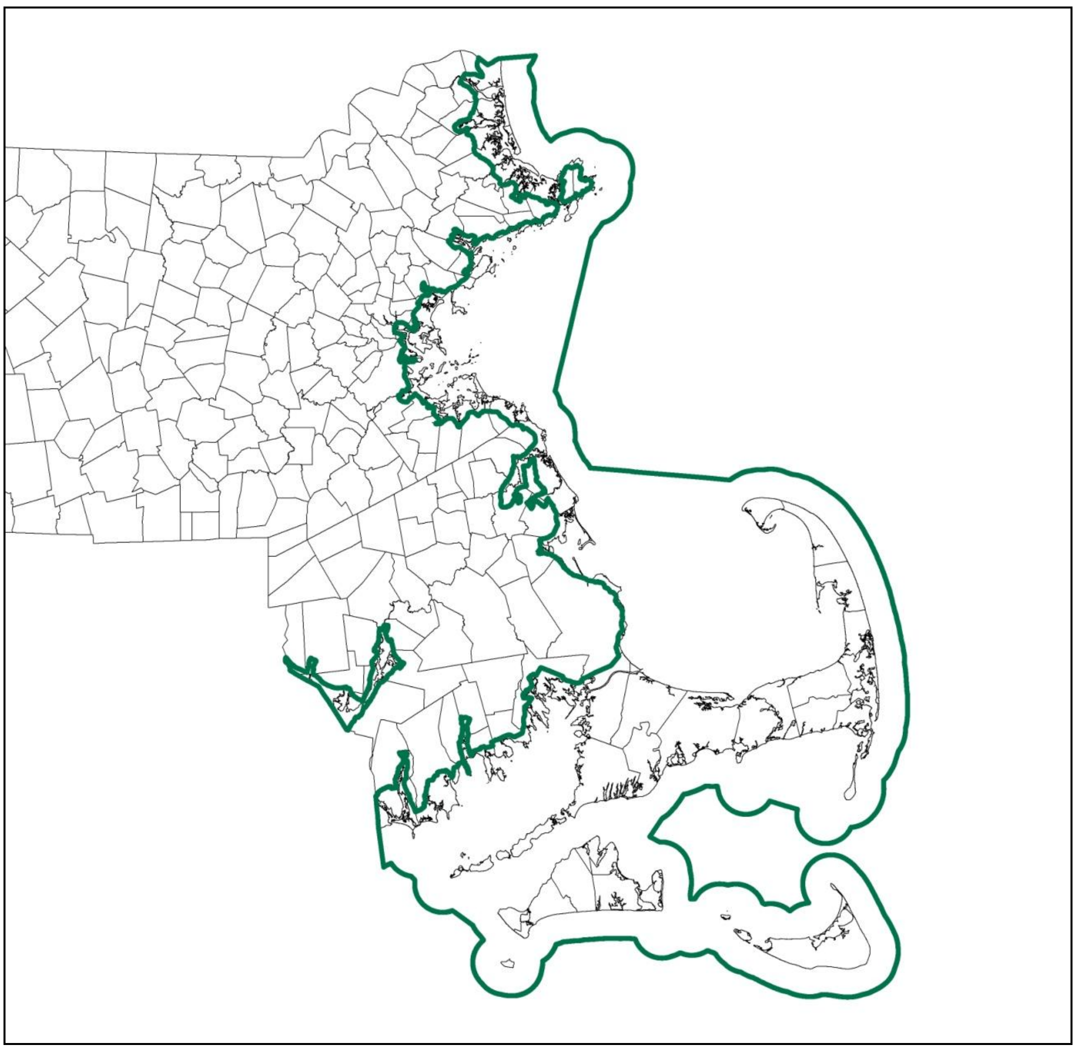


Figure 4-4: The Massachusetts Coastal Zone.

These data are from the MassGIS Coastal Zone datalayer.

Species of Greatest Conservation Need in Marine and Estuarine Habitats

Forty-three SGCN are assigned to Marine and Estuarine Habitats (Table 4.6).

Although classified as an anadromous fish, the Connecticut River Shortnose Sturgeon is almost never found in the open ocean, rather individuals spend their lives in the mainstem river undergoing migrations between discrete spawning, rearing, and feeding areas, including the estuary. Shortnose Sturgeon in the Gulf of Maine undertake short migrations at sea, moving between adjacent river systems. In fact, Shortnose Sturgeon tagged in the Merrimack River have been tracked to spawning areas in the Kennebec River in Maine.

Atlantic Sturgeon are anadromous, entering large freshwater river systems to spawn during the spring. Juvenile Atlantic Sturgeon are regularly found in the estuaries and lower portions of the Connecticut, Merrimack, and Taunton rivers during the summer months. While the closest river that still supports a significant spawning population is the Hudson, recent surveys by the Connecticut Department of Energy and Environmental Protection have found young-of-year Atlantic Sturgeon in the Lower Connecticut River. Both sturgeon species, as well as Blueback Herring, Alewives, American Shad, and American Eel, migrate through open ocean off Massachusetts, on their way to breed in freshwater or saltwater, depending on the species.

Sea turtles do not nest on Massachusetts beaches and islands, but the species above have been found to migrate through Massachusetts waters to feed and return to warmer waters before the onset of winter. Such behavior is generally undertaken by juvenile sea turtles. Northern Diamond-backed Terrapin are not true sea turtles; they live in saltmarsh and estuarine systems. Whales also move through Massachusetts waters, and regularly feed offshore, depending on prey availability. From March through November, a variety of whale species can be found in waters off the Massachusetts' Coast (e.g., Gloucester, Cape Cod) to feed on mackerel, herring, and krill, among other schooling fish that breed in these nutrient-rich waters.

The four species of rare terns that nest in Massachusetts are completely dependent on marine and estuarine habitats for all of their food. All four terns nest very close to salt water, on small islands, open beaches, or in the salt marsh. Common Eiders and Long-tailed Ducks gather in huge wintering flocks off the Massachusetts coast. Red-throated and Common loons are frequent migrants along the Massachusetts Coast during spring and fall migration, and both species can be found in these waters during the winter months (Common Loon being more abundant during this time). Leach's Storm-petrels are most commonly seen as migrants off Massachusetts, although a few pairs nest on Massachusetts islands. Black-crowned Night-Herons and other wading birds nest along the coast and on near-shore islands.

Adult American Shad enter coastal bays and estuaries in early spring (March-April) where they stage before beginning their migration to spawning grounds in freshwater rivers. Juvenile shad enter estuaries and coastal bays in the fall as zero-age migrants on their way to near-shore rearing habitat. Some juvenile shad will remain in the estuaries for up to 1 year before entering the ocean. Adult herring (Alewife and Blueback Herring) enter coastal bays and estuaries in early spring (March-April), where they stage before beginning their migration to spawning grounds in freshwater rivers. Juveniles begin migrating from their nursery areas to the sea in the fall, cued by heavy rainfall, high waters, or sharp declines in water temperatures. Some juvenile herring will remain in the estuaries for up to 1 year before entering the ocean. Schools of juvenile herring are a significant forage base in our estuaries and coastal bays.

The American Eel is a catadromous species, which spends most of its life in rivers, lakes, and estuaries, but migrates to the ocean to spawn. In spring, juvenile eels (known as glass eels) migrate into estuaries along the Atlantic coast where they become pigmented. These eels are known as elvers. Some elvers remain in the estuaries, but others migrate varying distances upstream, often for several hundred kilometers. Now in their yellow-eel phase, the American eels will remain in the brackish and fresh waters of these rivers for the majority of their lives, for at least 5 and possibly as many as 20 years. Females reach a maximum length of 5 feet, and males grow as long as 2 feet. Mature eels migrate downstream in the fall. Their migration is usually cued by significant rain events. Once at sea, the eels migrate to the waters of the Sargasso Sea to spawn. The migration occurs throughout autumn nights, with adults descending streams and rivers to the estuaries for January spawning in the warm Caribbean waters.

Table 4-6: Species of Greatest Conservation Need in Marine and Estuarine Habitats

Taxon Grouping	Scientific Name	Common Name
Fishes	*Acipenser brevirostrum*	Shortnose Sturgeon
	Acipenser oxyrinchus	Atlantic Sturgeon
	Alosa aestivalis	Blueback Herring
	Alosa pseudoharengus	Alewife
	Alosa sapidissima	American Shad
	Anguilla rostrata	American Eel
	Fundulus luciae	Spotfin Killifish
	Petromyzon marinus	Sea Lamprey
	Salmo salar	Atlantic Salmon
Reptiles	*Caretta caretta*	Loggerhead Sea Turtle
	Chelonia mydas	Green Sea Turtle
	Dermochelys coriacea	Leatherback Sea Turtle
	Eretmochelys imbricata	Hawksbill Sea Turtle
	Lepidochelys kempii	Kemp's Ridley Sea Turtle
	Malaclemys terrapin	Northern Diamond-backed Terrapin
Birds	*Anas rubripes*	American Black Duck
	Calonectris diomedea	Cory's Shearwater
	Clangula hyemalis	Long-tailed Duck
	Egretta thula	Snowy Egret
	Fratercula arctica	Atlantic Puffin
	Gavia stellata	Red-throated Loon
	Haliaeetus leucocephalus	Bald Eagle
	Larus argentatus	Herring Gull
	Larus atricilla	Laughing Gull
	Larus marinus	Great Black-backed Gull
	Morus bassanus	Northern Gannet
	Oceanodroma leucorhoa	Leach's Storm-Petrel
	Phalacrocorax auratus	Double-crested Cormorant
	Phalaropus fulicarius	Red Phalarope
	Phalaropus lobatus	Red-necked Phalarope
	Puffinus griseus	Sooty Shearwater
	Puffinus puffinus	Manx Shearwater
	Somateria mollissima	Common Eider
	Sternula antillarum	Least Tern
	Sterna dougallii	Roseate Tern
	Sterna hirundo	Common Tern
	Sterna paradisaea	Arctic Tern
Mammals	*Balaenoptera borealis*	Sei Whale
	Balaenoptera musculus	Blue Whale
	Balaenoptera physalus	Fin Whale
	Eubalaena glacialis	Northern Right Whale
	Megaptera novaeangliae	Humpback Whale
	Physeter macrocephalus	Sperm Whale

Threats to Marine and Estuarine Habitats

IUCN Threat 1: Residential and Commercial Development
Shoreline development has created the greatest threat to our coastal bays and estuaries. Massachusetts has lost close to 30% of its coastal wetlands due to development. While wetland protection laws passed in the 1970s have reduced large-scale wetland loss, incremental loss continues. The loss of coastal wetlands reduces the filtration ability provided by such wetlands to waters entering our bays and estuaries. Shoreline development results in more impervious surface with increased stormwater runoff and accompanying potential for sedimentation and toxic contamination. In addition, rapid stormwater runoff, accelerated because of development, shortens the time it takes for fresh water to enter the ocean, thus reducing estuarine areas by making them less saline.

IUCN Threat 2: Agriculture and Aquaculture
Coastal aquaculture in Massachusetts currently focuses on shellfish, but it potentially provides an opportunity for the fishing industry which is being faced with reduced wild fish populations. With aquaculture, concerns include the spread of disease to wild populations, eutrophication, and pollution. The extent to which aquaculture installations in marine and estuarine areas affects seabird use of those areas has not been explored in Massachusetts.

IUCN Threat 3: Energy Production and Mining
Water withdrawal for energy production, for both evaporative cooling and non-contact cooling water, can have major effects on estuarine systems. For example, the Brayton Point Station on Mount Hope Bay is the largest coal- and oil-fired power plant in New England. Currently, it is slated to close in 2017. However, when operated in open cycle, the plant withdrew nearly one billion gallons of water from the Bay and circulated it through the facility to condense the steam used to produce electricity. The water was then discharged back to the Bay at elevated temperatures of up to 95° Fahrenheit. Operation of this "once-through cooling system" damages or kills many aquatic organisms by entrainment into the cooling system and impingement on the exclusion racks, in addition to elevating water temperatures in the Bay. These effects were suspected as the cause for the collapse of the winter flounder population in Mount Hope/Narragansett Bay and, as a result, in 2007 the plant owner and the EPA entered into an agreement to end open-cycle operation. In addition, the plant constructed two 500-foot-tall natural-draft cooling towers, allowing closed-cycle operation with all cooling water recycled to the plant and no heated water discharged to the Bay (http://www.epa.gov/region1/braytonpoint/).

Off-shore wind turbine installations can cause mortality to birds and bats and may alter and reduce habitat available for nesting or foraging. Off-shore wind turbines may also negatively impact sea mammals and other organisms. Sand mining of near-shore areas could reduce foraging habitat and prey for sea ducks, terns, and other birds that rely on shoals and other shallow-water features for foraging.

IUCN Threat 4: Transportation and Service Corridors
Regular oil barge traffic through Buzzards Bay and Cape Cod Bay remains a constant threat to Massachusetts' highest concentrations of vulnerable coastal birds. A major oil spill that occurred in Buzzards Bay in April 2003 resulted in oiling of two of the three largest Roseate Tern nesting islands in North America at the beginning of the nesting season; oiling at one of them was severe.

Ships carrying oil or other cargo continue to be a threat and a source of mortality to whales due to collisions with the vessels. To reduce this risk, after identifying where whales are most commonly documented, shipping lanes through the Stellwagen Bank National Marine Sanctuary were modified in 2006 to help protect whales.

IUCN Threat 5: Biological Resource Use
Commercial Fishing: In 2013, NOAA reported that New Bedford retained its title as the top U.S. port in fish revenues for the 14th straight year. Massachusetts 2013 commercial fisheries landings were valued at nearly $557 million, second only to Alaska. The same year, Acting U.S. Secretary of Commerce Rebecca Blank declared a commercial fishery failure in the Northeast groundfish fishery. Despite years of careful management, the Gulf of Maine cod stock is now reported to be at its lowest level ever, down to as little as 3% of what it would take to sustain a healthy population. That was down from between 13% and 18% in the last assessment in 2011. This shows how commercial fisheries can severely affect target fish populations. In addition, the indirect effects of commercial fishing activities like bycatch (the discard of

unreported and often dead non-target species) and effects of environmentally damaging gear types like bottom trawls can add to changes in fish abundance, which can ripple throughout the food web causing dramatic changes in species richness and community structure (Engel and Kvitek 1998, Jones 1992). The overharvesting of fish can negatively impact the seabirds that forage on them, and declines in Red Knot populations have been linked to the overharvest of horseshoe crabs (Niles et al. 2009). Commercial fishing also poses a threat to whales and other sea mammals through entanglement with fishing gear. In fact, in a study examining the cause of whale mortalities in the northwest Atlantic between 1970-2009, human interaction was deemed the cause in 67% of mortalities, with fishing gear entanglement being the most common (Van Der Hoop et al. 2012).

IUCN Threat 6: Human Intrusions and Disturbance
Marine and estuarine animals are subject to injury or death from ship collisions, entanglement with nets, ingestion of anthropogenic objects (such as garbage, debris, and objects washed off ships), declines in prey species, pollution, disturbance of nesting or breeding areas, and, in some cases, harvesting of adults or eggs.

IUCN Threat 7: Natural System Modifications
Natural system modifications are not a major threat to marine and estuarine habitats in Massachusetts. (Note, however, that dams and under-sized culverts can impede salt and brackish water flows significantly; these effects are explored in detail in the Salt Marsh habitat narrative.)

IUCN Threat 8: Invasive and Other Problematic Species and Genes
A number of invasive species have taken hold in these habitats and threaten native species. These include Common Reed (*Phragmites*) and Purple Loosestrife.

At least 17 species of nonnative marine algae have been documented in Massachusetts. The most widespread nonnative seaweed species in Massachusetts is arguably the red filamentous algae *Neosiphonia harveyi*, followed by the green algae *Codium fragile* ssp. *fragile* (CZM 2013a, Pederson et al. 2005). More recent invaders include the red algae *Grateloupia turuturu*, first documented in Massachusetts in 2007; *Heterosiphonia japonica*, first discovered in 2010; and *Colpomenia peregrine* , first found in 2011 (Massachusetts Coastal Zone Management 2013, Green et al. 2012, Low et al. 2011, Mathieson et al. 2008d, Schneider 2010). Harmful marine algal blooms (e.g., "red tide") may cause mortality of wildlife, especially seabirds.

IUCN Threat 9: Pollution
Overflows and leaks from wastewater treatment plants and faulty septic systems can result in bacterial and pathogenic contamination and increase nitrogen loading in our coastal waters. This, in turn, promotes algae growth on eelgrass beds, to the detriment of this valuable aquatic food and cover source for fish, shellfish, marine invertebrates, waterfowl, and other aquatic birds. High nutrient levels also cause overcrowding of plants, leading to increased competition for sunlight.

Similarly, increased commercial and recreational boat traffic resuspends sediments, further shading submerged vegetation. Direct discharge of waste from recreational boating and accidental oil spills from commercial shipping have been threats in the past and will continue to be in the future.

Regular oil barge traffic through Buzzards Bay and Cape Cod Bay remains a constant threat to Massachusetts' highest concentrations of vulnerable coastal birds. A major oil spill that occurred in Buzzards Bay in April 2003 resulted in oiling of two of the three largest Roseate Tern nesting islands in North America at the beginning of the nesting season; oiling at one of them was severe.

Increasingly, marine cables and pipelines are being proposed for construction, but these may bring the threat of fuel leaks and other types of pollution or contaminants associated with these structures.

IUCN Threat 10: Geological Events
Geological events are not a major threat to this habitat in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Climate change could affect coastal areas in a variety of ways. For summaries of current and predicted changes to nearshore waters and sea levels in Massachusetts, see the Massachusetts Climate Change Adaptation Report (Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee 2011) and the recent report from the Northeast Climate Change Center*, Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans* (Staudinger et al. 2015).

Coasts are sensitive to sea level rise, changes in the frequency and intensity of storms, increases in precipitation, and warmer ocean temperatures. In addition, rising atmospheric concentrations of carbon dioxide are causing the oceans to absorb more of the gas and become more acidic. This rising acidity could have significant impacts on coastal and marine ecosystems.

The impacts of climate change are likely to exacerbate many problems that coastal areas already face, such as shoreline erosion, coastal flooding, and water pollution.

During the 20th century, global sea level rose by roughly 7 inches (Nicholls et al. 2007), and climate-change models project that global sea level rise will accelerate in the 21st century. Models based on the thermal expansion of seawater and ice melt estimate that global sea levels will rise approximately 20 to 39 inches by the end of the century (NRC 2011). However, due to uncertainties about the response of ice sheets to warmer temperatures and future emissions of greenhouse gases, higher values are possible.

Rising sea levels can inundate coastal freshwater and upland habitats, increase the salinity of ground water, and push salt water further upstream. This salinity may make water undrinkable without desalination, and harms aquatic plants and animals that cannot tolerate increased salinity (Nicholls et al. 2007). Sea level rise will also magnify the impacts of storms by raising the storm surge.

In addition to rising, coastal waters have warmed during the last century, and are very likely to continue to warm by as much as 4° to 8°F in the 21st century. This warming may lead to major changes in coastal ecosystems, affecting species that inhabit these areas. Warming coastal waters are causing suitable habitats of temperature-sensitive species to shift northward. Suitable habitats of other species may also shift because they cannot compete for limited resources with the southern species that are moving northward. Invasive species that had not been able to establish populations in colder environments may now be able to survive and start competing with native species (Karl et al. 2009). Rare salt marsh plants may be lost with a rise in sea levels at a rate faster than the species can move latitudinally to more suitable climates or altitudinally to higher ground.

The ocean has become more acidic over the past few centuries because of increased levels of atmospheric carbon dioxide, which dissolves in the water. Higher acidity affects the balance of minerals in the water, which can make it more difficult for certain marine animals to build their skeletons and shells (Karl et al. 2009).

Conservation Actions

Direct Management of Natural Resources
This action is not a high priority for the marine and estuarine habitats in Massachusetts.

Data Collection and Analysis
Monitor and conduct surveys of birds and other organisms in marine and estuarine waters, so that changes in abundance and distribution can be detected and threats can be evaluated. This would include the temporal and spatial use of the marine environment by birds and bats; documenting stranded or oiled sea turtles (including carcasses), marine mammals, and birds; and investigating interactions between fisheries/aquaculture harvests and seabird abundance and productivity. Other actions include mapping eelgrass beds through aerial surveys and working with non-governmental organizations on volunteer wetland assessment programs.

Education and Outreach
Provide technical advice and outreach on pollution and stormwater issues to coastal municipalities and the public along coastal Massachusetts.

Harvest and Trade Management
Steps should be taken to reduce marine mammal mortalities as a result of entanglement with fishing gear.

Land and Water Rights Acquisition and Protection
Siting of lease areas for aquaculture, wind energy facilities, and other uses should take into account use of those areas by sea ducks, seabirds, marine mammals, and other potentially affected organisms.

Law Enforcement

Increase law enforcement capacity on the water to protect estuarine and marine habitats and the species that inhabit them.

Limit human activities around nesting islands, sand bars, and beaches during the nesting seasons of coastal and marine birds.

Work to reduce turbidity caused by boat and recreational watercraft traffic in important eel grass beds.

Law and Policy

Enforce and implement the Massachusetts Ocean Sanctuaries Act (MGL chapter 132A, section 14).

Support legislation to minimize the risk of catastrophic oil spills.

Pursue a "No Discharge Area" plan for developing guidelines for personal watercraft use.

Planning

Develop detailed conservation and recovery plans for SGCN associated with marine and estuarine habitats. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Implement pre-oil-spill planning so that critical coastal waterbird nesting sites are preidentified and prioritized in response actions. Develop methods to physically shield the most critical sites.

Identify areas that could host offshore wind or tidal energy facilities that minimize the risk to wildlife.

Review and evaluate existing and proposed marine cables and pipelines for potential negative impacts on wildlife.

Continue to identify areas with high densities of whales, to evaluate and potentially modify current shipping lanes.

Identify coastal areas that are most vulnerable to flooding and erosion and develop plans to mitigate impacts from flooding.

Species Reintroduction and Stocking

State and Federal natural resource management agencies are actively engaged in diadromous fish restoration programs that involve species reintroduction through:

1. Dam removals or installation of fish passages to allow fish to repopulate previously inaccessible habitat.
2. Trap-and-truck programs that stock spawning adults into vacant habitat with the expectation of producing self-sustaining populations.

These restoration programs should be continued.

Links to Additional Information

- NOAA Commercial Fisheries Statistics
- NOAA Fisheries Service declaration of northeast groundfish fishery disaster
- NOAA Fisheries Service statement regarding decline in Gulf of Maine cod stock
- 2015 Massachusetts Ocean Management Plan – downloadable PDF

Upland Forests: Introduction

In this Plan, we include four types of upland forests, each as their own SWAP Habitat:

- Transition Hardwoods-White Pine Upland Forest
- Northern Hardwoods-Spruce Fir Upland Forest
- Central Hardwoods-White Pine Upland Forest
- Pitch Pine-Oak Upland Forest

These upland forests share many characteristics, including threats and thus potential conservation actions. Here, we provide a general introduction to all types of upland forest in Massachusetts, separate descriptions of each of the four major types we recognize as SWAP Habitats, and, finally, a unified threats and conservation actions section.

General Habitat Description

Upland forest is land dominated by tree cover, where the soils are not saturated by water for extensive portions of the growing season. Upland forest *habitat* occurs in areas of upland forest that are large enough to provide habitat for one or more wildlife species. From less than a millennium after the last deglaciation up until today, upland forest has provided the most extensive wildlife habitats in what is now the State of Massachusetts (Shuman et al. 2004). In 2011, between 53% or 2.7 million acres (Jin et al. 2013) and 58% or 3.0 million acres (Butler et al. 2012) of the 5.2 million acres in Massachusetts is estimated to be forested, and over 95% of that forest is upland (96% upland forest vs. 4% wetland forest, according to a DFW analysis combining the National Landcover Database and the MassGIS DEP wetlands data layer; Figure 4-5 and Table 4-7). Note that not all acres of upland forest are capable of providing adequate habitat, especially in areas with higher concentrations of human development, where forest patches may be smaller than what is required by specific wildlife species.

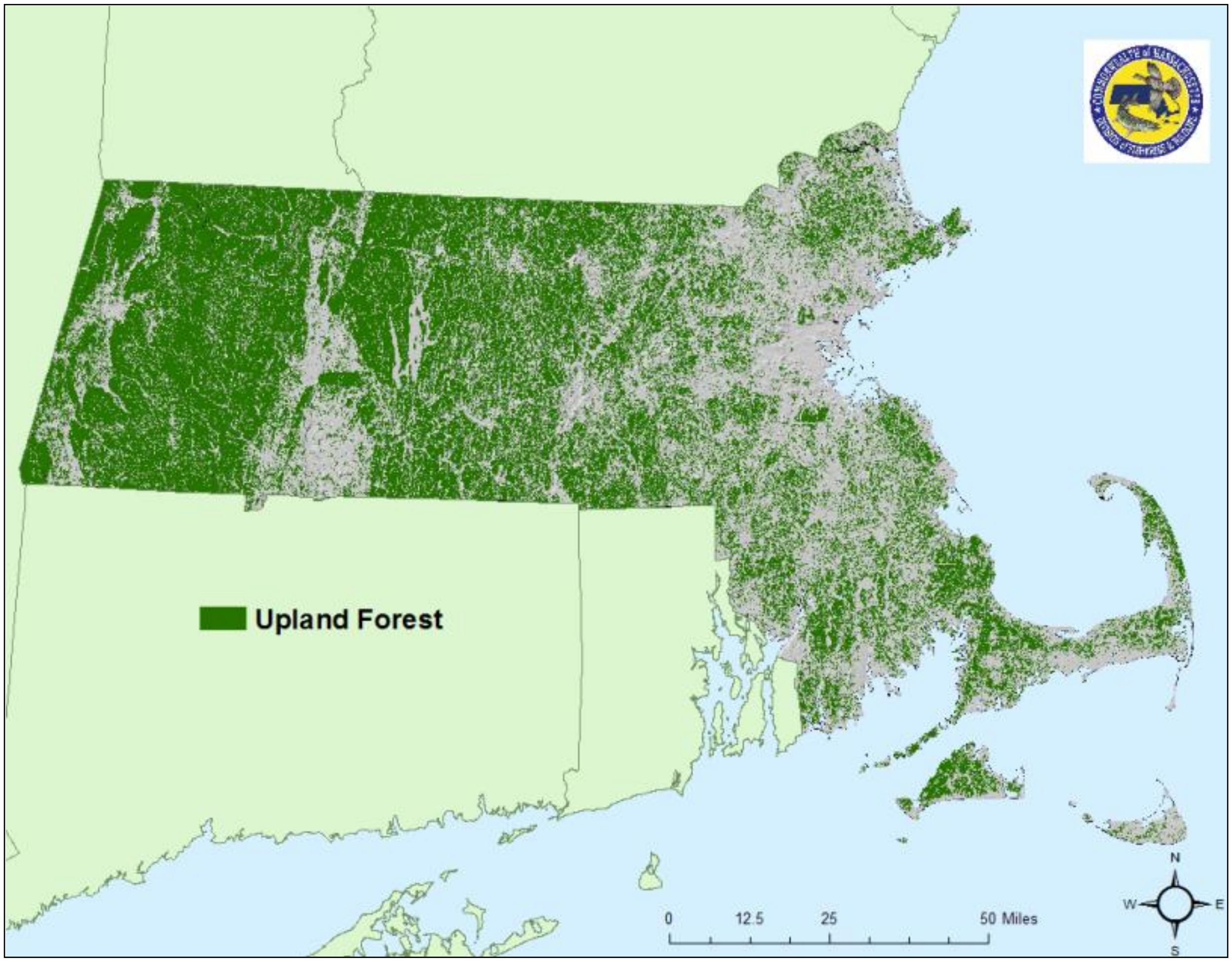


Figure 4-5. Upland Forest in Massachusetts in 2011.

Data from National Land Cover Database (Jin et al. 2013) and 2009 MassGIS DEP Wetlands (DEP Staff 2009).

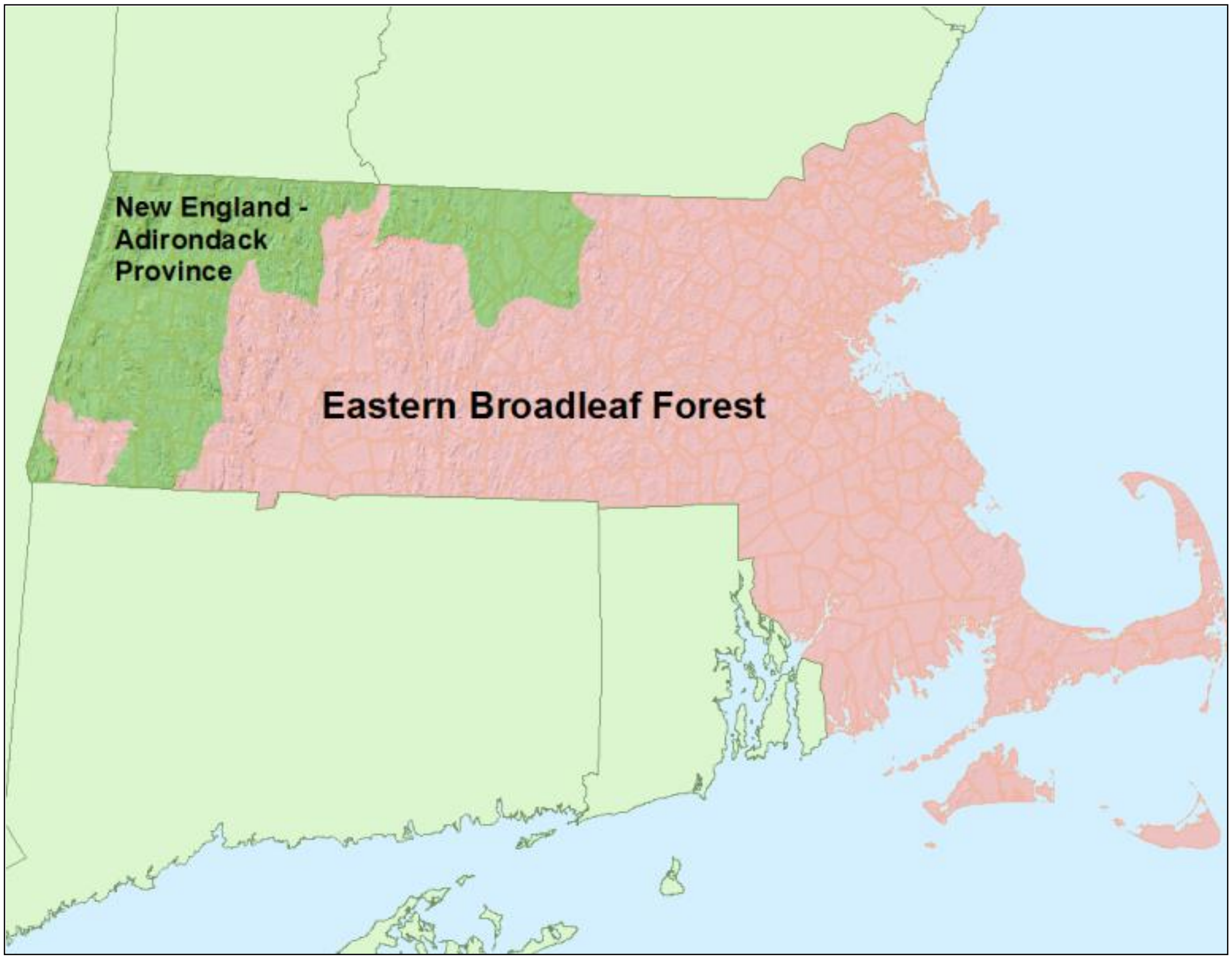


Figure 4-6. Ecoregional Provinces in Massachusetts.

At the time of European settlement, presettlement land survey records show that Massachusetts forests were characterized by two general forest types: northern hardwoods (Beech-Birch-Maple-Hemlock-Spruce/Fir) and central hardwoods (Oak-Hickory-Pine; Cogbill et al. 2002). These forest types were separated by a relatively discrete "tension zone" that corresponded to physiographic conditions, climate, and fire regime. This tension zone closely parallels the current U.S. Forest Service boundary between the New England–Adirondack and the Eastern Broadleaf Forest ecological provinces (Keys, et al. 1995) (Figure 4-6). Today, transitional mixtures of northern hardwood and central hardwood forest occur commonly in many portions of Massachusetts as a result of a dramatic alteration of the forest landscape throughout the 18th and 19th centuries associated with exploitive logging practices, the conversion of forest to agriculture, and the subsequent abandonment of agriculture that led to the emergence of today's second-growth forest (Foster et al. 1998).

The forests we see today in Massachusetts are still recovering from the dramatic alteration that occurred in the 18th and 19th centuries. In addition, today's forests are also responding to established impacts from invasive organisms, such as chestnut blight, butternut canker, and Dutch elm disease (http://www.treesearch.fs.fed.us/pubs/745), as well as ongoing and increasing impacts such as beech-bark-disease complex (http://na.fs.fed.us/fhp/bbd/), Hemlock Wooly Adelgid (http://na.fs.fed.us/fhp/hwa/), and, most recently , Asian Longhorned Beetle (http://www.na.fs.fed.us/fhp/alb/) and Emerald Ash

Borer (http://na.fs.fed.us/fhp/eab/ or http://www.emeraldashborer.info/). Massachusetts forestlands are also being impacted by elements of human-accelerated climate change (Rustad et al. 2012) such as increasing growing season length, more extreme summer temperatures, and longer and more frequent periods of summer drought, as well as by more frequent freeze-thaw cycles in winter (http://nsrcforest.org/sites/default/files/uploads/templer09full.pdf). Climate change appears to be at least partially responsible for the recent and rapid spread of native insect pests, such as the Southern Pine Beetle, into more northern climes (Gan 2004). Southern Pine Beetle has very recently been identified as causing extensive mortality of pitch pine on Long Island, and could soon cause similar mortality in the pitch pine forests of southeastern Massachusetts.

DeGraaf et al. (2007) provide a useful description of today's forests that reflects the dramatic human alterations of recent centuries described above. These authors divide New England forest habitat into six forest regions (Figure 4-7):

- Spruce-Fir;
- Northern Hardwoods-Spruce;
- Northern Hardwoods;
- Transition Hardwoods-White Pine;
- Central Hardwoods –Hemlock-White Pine;
- Pitch Pine-Oak.

All of these regions occur in Massachusetts; however, the first two are limited in extent. Therefore, for the purposes of this plan, DFW groups the first three regions together into a Northern Hardwoods-Spruce-Fir region, leaving us with four distinct regions of forest habitat (Table 4-7; Figure 4-8):

- Northern Hardwoods-Spruce-Fir;
- Transition Hardwoods-White Pine;
- Central Hardwoods-White Pine;
- Pitch Pine-Oak.

The distributions of these forest habitat types in Massachusetts are determined by latitude, elevation, soils, and human land-use history.

Individual forest cover types that describe the specific proportion of tree species are typically mapped at a local scale (e.g., on a parcel by parcel basis). Given that the major upland forest habitat regions are mapped at a more extensive landscape scale, numerous individual forest types often occur within a single major habitat region.

From a landscape-scale, wildlife-habitat perspective, the climatic, edaphic, and other variables that influence the distribution of individual forest types into major regions also influence the wildlife living in those regions. For this reason, we use the four forest habitat regions described above as our four major upland forest habitat types in Massachusetts (Table 4-7). It should be recognized, however, that these regions are approximations for the location of the habitat types themselves. Wildlife that rely on specific features of an individual forest cover type, such as availability of a particular species of understory vegetation or overstory tree, may occur wherever that forest type is found, rather than being limited to a given major forest region.

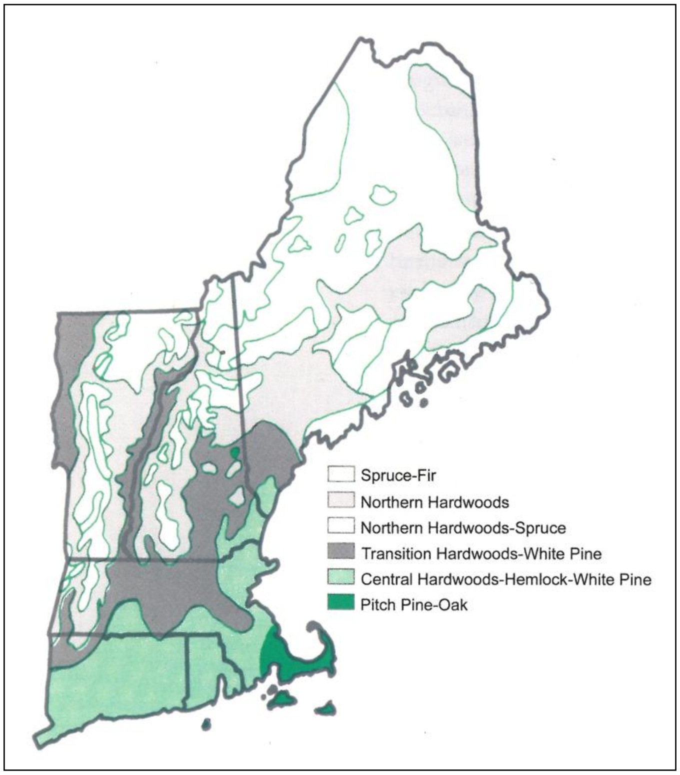


Figure 4-7. Forest regions of New England.

From DeGraaf et al. (2007). © University Press of New England, Lebanon, NH. Reprinted with permission; map on Page 10, Fig. 5.

Table 4-7. Major upland forest habitat regions (DeGraaf et al. 2007) in Massachusetts.

Based on 2011 National Land Cover Database (Jin et al. 2013) and MassGIS wetlands data (DEP Staff 2009).

Forest Habitat Region	Total area (thousand acres)	Forest (thousand acres / % of total area)		Upland Forest (thousand acres / % of forest)	
Northern Hardwoods-Spruce-Fir	772	624	81%	605	97%
Transition Hardwoods-White Pine	2,041	1,234	60%	1,182	96%
Central Hardwoods- White Pine	1,749	652	37%	607	93%
Pitch Pine-Oak	616	235	38%	228	97%
Total	5,179	2,744	53%	2,623	96%

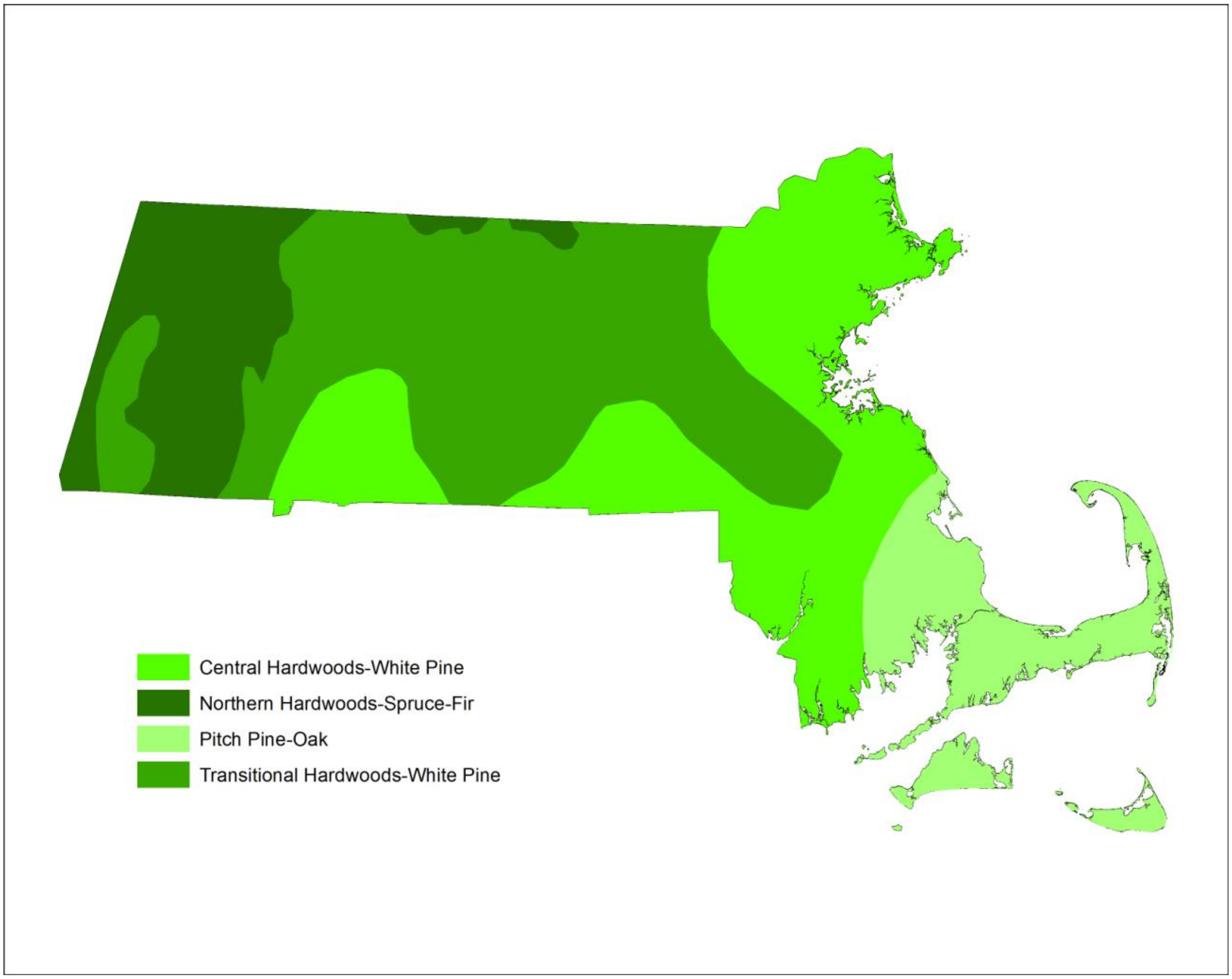


Figure 4-8. Upland Forest SWAP Habitats.

Note these are generalized boundaries. Adapted from DeGraaf et al. 2007.

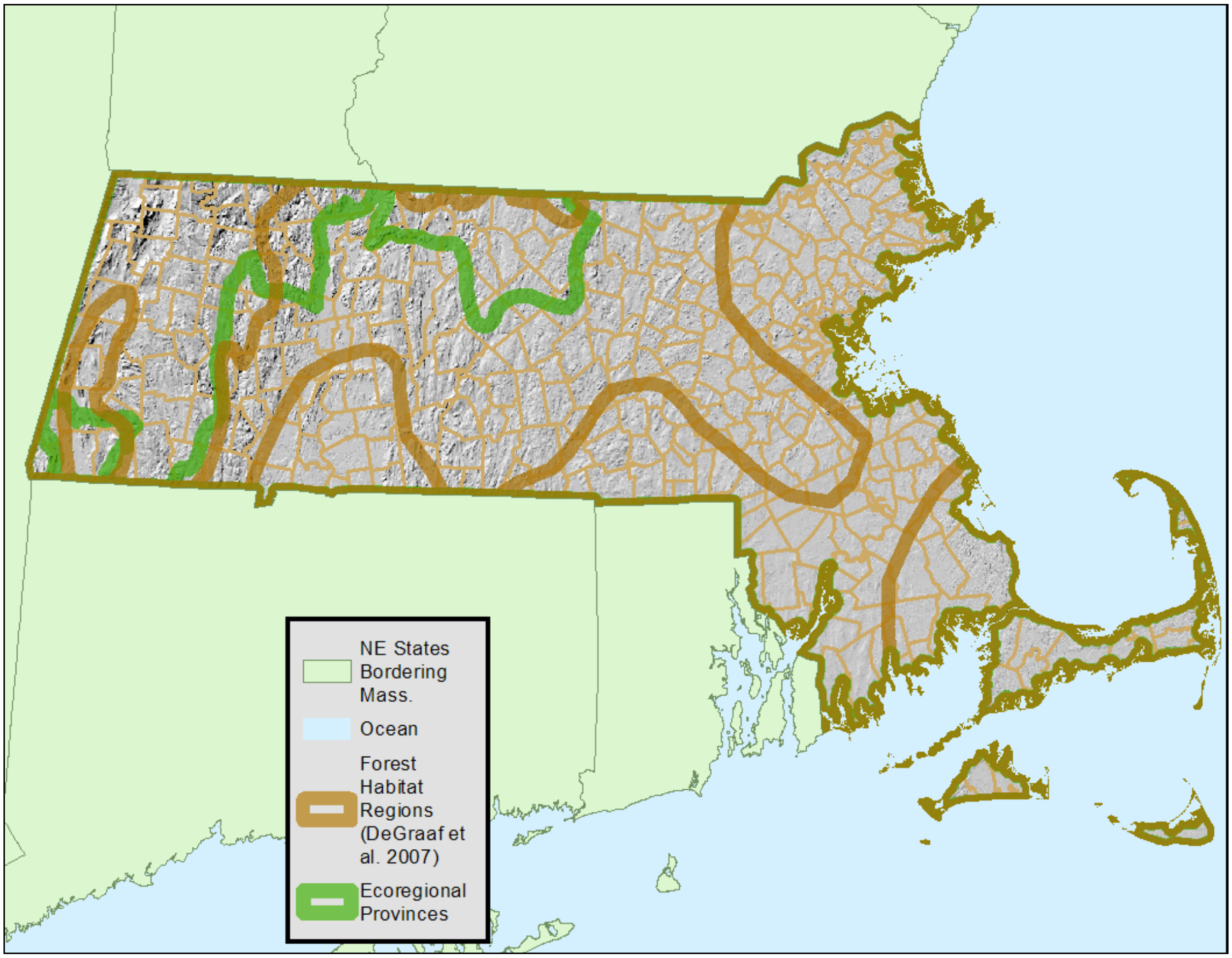


Figure 4-9. USDA Forest Service ecoregional provinces in comparison with forest regions.

Adapted from DeGraaf et al. 2007.

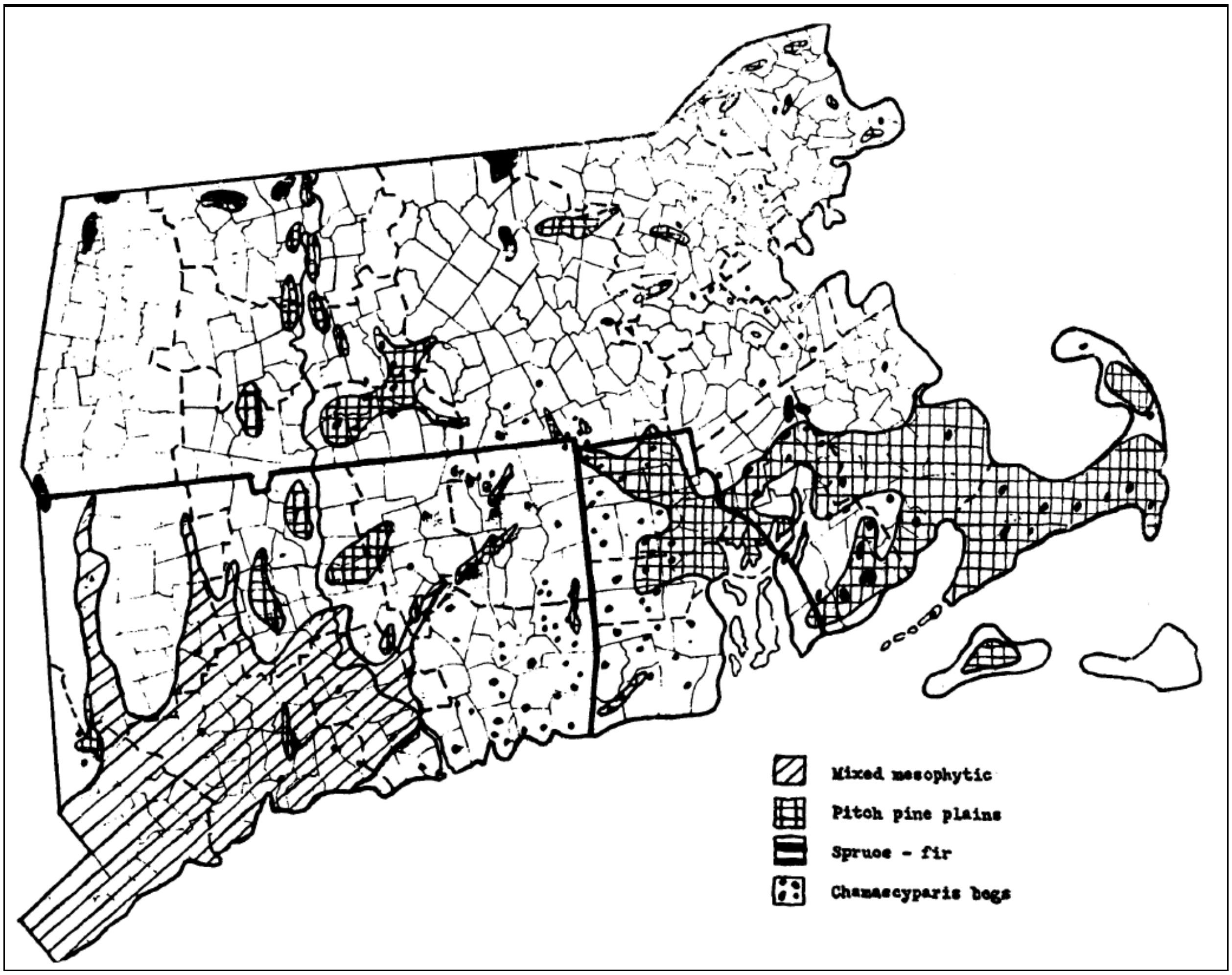


Figure 4-10. Patches of certain forest types remaining in 1935.

Including Pitch Pine plains, shown cross-hatched, from Bromley (1935) © Ecological Society of America. Reprinted with permission; map on Page 77, Fig. 2.

If we look at the map of pre-European settlement forest types overlaid with the map of today's forest regions (Figure 4-9) we can see how the original northern hardwood-spruce/fir forest receded west into the more broken terrain and higher elevation of the Berkshire hills, the oak-hickory-white pine forest type receded south and east toward lower elevations of the landscape with more of a coastal influence, and a new transitional forest type emerged between the two. What happens to the composition and distribution of transitional forest in the future depends on several factors, including impacts of invasive plant and insect species, intensity of wood products harvesting, and influences of climate change, all of which can affect both the survival of mature trees and the establishment of new ones.

The Transition Hardwoods-White Pine region contains a diverse group of forest types, including mixtures of northern hardwood species (e.g., beech, birch, and maple), central hardwood species (e.g., oak and hickory), and softwood species (especially White Pine). These transitional forest types occur where past and ongoing human land-use has blurred the line between the more distinct Northern Hardwoods-Spruce-Fir and Central Hardwoods-White Pine types. While the transitional forest types are most common in the area between the Northern Hardwoods-Spruce-Fire and Central Hardwoods-White Pine regions, examples of these forest types can also be found deep within either region, and even in areas of the Pitch Pine-Oak region. Conversely, smaller areas of the more northern or central forest types may occur within the transitional region, and there is even a significant occurrence of inland pitch pine-oak forest (Montague Plains) within the transitional region (Figure 4-10).

The Northern Hardwoods-Spruce-Fir region of the higher elevation and more inland areas of the northern Berkshire plateau of Western Massachusetts and the Worcester-Monadnock plateau of north-central primarily contains upland forest habitat of three types: northern hardwoods forests of beech-birch-maple, northern hardwood-spruce forest, and spruce-fir forest. However, smaller areas of other forest types also occur within this region, such as northern hardwood-hemlock-white pine or transitional forest types. Most of the small amount of remnant original biologically mature forest (“old growth”) occurs within this region.

The Central Hardwoods-White Pine region of the lower-elevation and more coastal areas of eastern and south-central Massachusetts primarily contains various central hardwoods, mixed hardwood/softwood, and softwood forest habitat types (e.g., oak-hickory hardwood forests, central hardwoods-white pine, hemlock-white pine), although smaller areas of transitional forest types and pitch pine-oak may also occur.

The Pitch Pine-Oak region of the coastal areas of southeastern Massachusetts is dominated by forests, shrublands, and open habitats, dominated by pitch pine and both tree- and shrub-oak species. These forest types also occur as inclusions in the other major forest regions. The distribution of pitch pine-oak forests is predominantly determined by glacial history and soil type, requiring the relatively infertile, deep sandy soils of glacial river deltas, outwash plains, and other glacial sand deposits, such as portions of the Connecticut River valley in central Massachusetts, other much smaller sand plains, and a few dry rocky ridge-tops in southwestern Massachusetts.

All of the upland forest types provide valuable structural attributes such as tree cavity den sites (which are utilized by a variety of bird and mammal species) and large woody material (which is utilized by various amphibian, reptile, and invertebrate species). Perhaps the biggest difference in wildlife habitat between forest types in Massachusetts is that oak acorn production, an important source of wildlife food, is substantially greater in Pitch Pine-Oak and Central Hardwood forest types than in northern forest types, while beech nut production is greater in northern hardwood types. Oaks and acorns play a fundamental role in the organization and dynamics of eastern wildlife communities (Healy et al. 1997) and beech nuts are influential in population levels of wildlife species such as Black Bear (LaMere 2012).

While some species of wildlife do not occupy upland forest, and instead require wetland or other aquatic habitats, upland forests provide important filters along wetlands, rivers, and streams. These filters affect wetland and aquatic habitats and the wildlife species that use such habitats. These forests provide energy to the streams in the form of allocthonous material (e.g., leaves and associated nutrients from the organic material). Small streams rely on this energy almost exclusively to initiate their trophic interactions and food webs. Upland forests, through their root systems, also serve to stabilize soils and sediments in high-gradient streams, thus minimizing erosion. Finally, upland forests help to moderate and regulate the temperature regime and fluctuations by providing shade to small streams. In addition, upland forests provide important habitat for wildlife species that occupy vernal pools throughout Massachusetts. With the exception of the few wildlife species that are restricted to coastal, grassland, or shrubland habitats, upland forests provide either direct or indirect habitat benefits to a substantial number of wildlife species of conservation concern in Massachusetts.

Transition Hardwoods-White Pine Upland Forest

Habitat Description

The fact that Transition Hardwoods-White Pine is by far the most abundant of the four major upland forest habitat types in Massachusetts (Table 4-7) speaks to the immense and enduring impact that human land-use history has had on our forestlands. The original mosaic of primary forest that blanketed what is now Massachusetts prior to European settlement was so profoundly disrupted by land-clearing, agricultural conversion, and subsequent agricultural abandonment over a 200-year period between about 1650 and 1850 that tree species assemblages are still sorting themselves out from this disruption more than a century and a half after the fact.

We know a great deal about why this happened (land grants from the King of England to European settlers that required clearing and 'improvement' of granted lands, wood exports to Europe, wood used for railroad ties and fuel, etc.), but understand less about the ecology of how it happened. What factors resulted in the contraction of both the original Northern Hardwood-Spruce/Fir and Oak-Hickory-White Pine forest types that originally dominated the two ecological provinces of Massachusetts (Figure 4-6) and the establishment of a new transitional forest containing elements of both the original Northern Hardwood-Spruce/Fir and Oak-Hickory-White Pine forest types (Figure 4-7)? The answer to this question greatly impacts the wide diversity of wildlife habitats and forested natural communities (Table 4-8) we see today throughout our most abundant habitat type.

Part of the answer lies in the structure of vegetation found in abandoned agricultural lands at the time reforestation began to occur (about 1850-1900), part in the seed dispersal mechanisms and shade tolerance of different tree species, and part in differing patterns of abandonment. Most agricultural lands in Massachusetts during the 1800s were used for grazing livestock (sheep and cattle), a lesser amount for growing hay, and a still lesser amount for growing row crops like vegetables and grains. When these various agricultural uses were ended, the soil was typically covered in a thatch of herbaceous vegetation, which was not especially accommodating to some types of tree seed but could be exploited by other types of tree seed. If grazing animals were removed gradually, rather than abruptly, preferential browsing of different tree species seedlings by livestock also impacted the eventual composition of the resulting forest.

For trees to successfully establish on abandoned agricultural lands, their seeds first needed to reach these abandoned fields (there weren't many trees left to provide seed), those seeds then needed to penetrate the thatch of herbaceous vegetation typical of post-agricultural conditions to make contact with the soil, the delicate seedling trees that germinated needed to be able to grow well in the relatively harsh, dry conditions of full sunlight, and the seedlings needed to escape browsing by remnant livestock. Accordingly, the emerging second-growth forest that first became established on abandoned agricultural lands was relatively simple in species composition because it was limited to tree species with seeds that:

1. could be distributed relatively long distances on the wind;
2. were shaped in such a way as to be able to wriggle their way through a thatch of herbaceous vegetation to make contact with the soil in order to germinate;
3. were at home growing in full sunlight even during the delicate seedling stage of life; and
4. were not preferentially browsed by any residual livestock.

Table 4-8. Terrestrial forest natural communities within Transition Hardwoods-White Pine Upland Forest.

Data from Swain and Kearsley (2015). SRANK (State Rank) ranges from S1 (Critically Imperiled in Massachusetts) to S5 (Secure in Massachusetts). Communities ranked S1-S3 (in bold) are considered Priority Natural Communities.

Natural Community Name	SRANK
Mixed Oak Forest / Woodland	S5
Northern Hardwoods - Hemlock - White Pine Forest	S5
Oak - Hemlock - White Pine Forest	S5
Successional Northern Hardwood Forest	S5
Successional White Pine Forest	S5
White Pine - Oak Forest	S5
Chestnut Oak Forest / Woodland	S4
Dry, Rich Oak Forest / Woodland	S4
Forest Seep Community	S4
Hemlock Forest	S4
Oak - Hickory Forest	S4
Pitch Pine - Oak Forest / Woodland	S4
Red Oak - Sugar Maple Transition Forest	S4
Black Oak - Scarlet Oak Woodland	**S3S4**
Open Oak Forest / Woodland	**S3**
Rich, Mesic Forest Community	**S3**
Hickory - Hop Hornbeam Forest / Woodland	**S2**
Pitch Pine - Scrub Oak Community	**S2**
Ridgetop Pitch Pine - Scrub Oak Community	**S2**
Calcareous Forest Seep Community	**S1**
High Elevation Spruce - Fir Forest / Woodland	**S1**
Yellow Oak Dry Calcareous Forest	**S1**

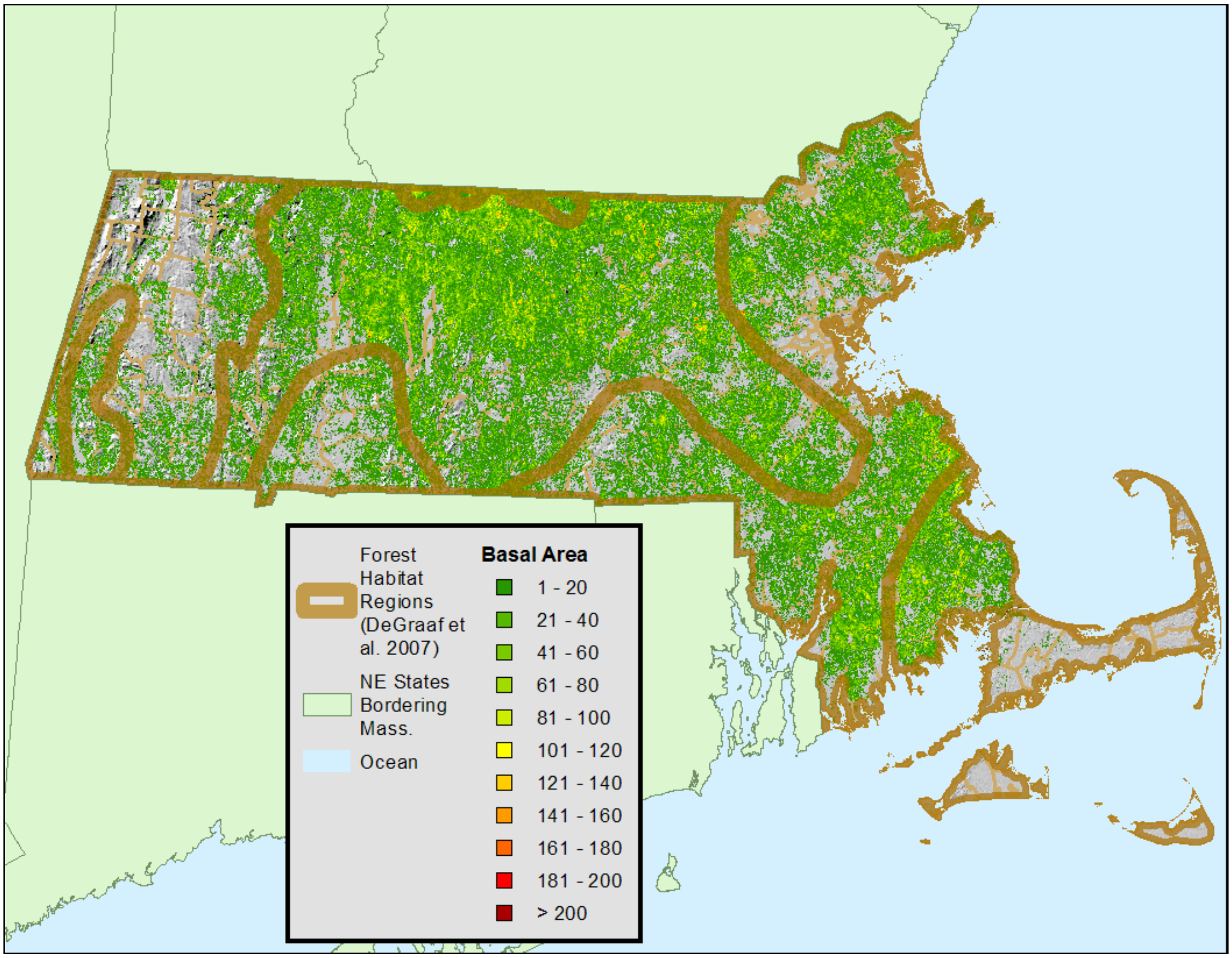


Figure 4-11. Occurrence of White Pine in Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

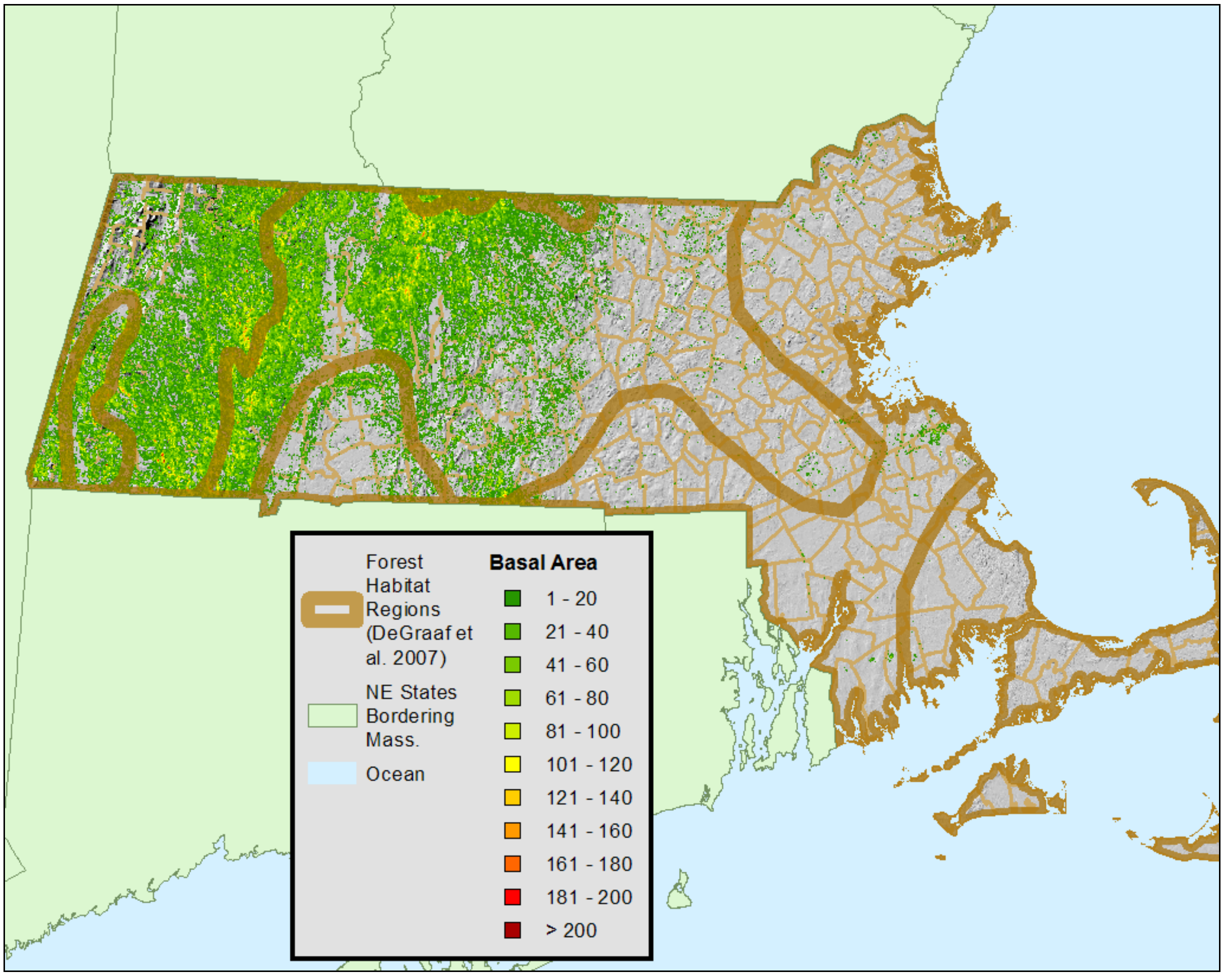


Figure 4-12. Occurrence of hemlock in Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015)

Without question, the tree species that was best able to take immediate advantage of post-agricultural conditions and dominate the early second-growth forest throughout Massachusetts was White Pine (Figure 4-11). This species had long been a ubiquitous component of both the Oak-Hickory and Northern Hardwood forests, but had nonetheless tended to be a relatively minor component, occurring most commonly along sandy river valley soils that were subject to occasional disturbance by spring flooding and associated ice-scouring. The scale-like seed of White Pine can ride for miles on the wind and, once it lands in abandoned fields, the seed shape allows it to wriggle downward as wind ruffles the thatch. After the seed finally touches the soil, it germinates readily and the young seedling can grow in dry conditions under full sunlight. The term “Old Field White Pine” is well-established in New England literature, and it is a combined artifact of human land-use history, seed ecology, and shade tolerance that resulted in a minor component of the pre-colonial forest becoming the most abundant tree in Massachusetts during the early twentieth century.

In addition to White Pine, a few other tree species were initially able to successfully exploit post-agricultural conditions during the late 1800s, especially in fields that were abandoned abruptly. For example, Gray Birch and White Birch have wind-disseminated seed that, while not scale-shaped, is still small enough to penetrate the thatch of old fields, and is even better able to grow under conditions of full sunlight than White Pine. The fluffy seeds of aspens travel long and far on the wind and aspen seedlings thrive in open sunlight, but the seeds typically need exposed soil to germinate. Spring brush fires in abandoned agricultural lands often created ideal conditions for aspen to establish. However, stands of these mostly short-lived birch and aspen species have been replaced during the century since the post-agricultural period, and represent only a small fraction of the current-day forest (Figure 4-13). Longer-lived, but still light-seeded species, such as Yellow Birch and Black (or Sweet) Birch, have become more dominant in the 20th and 21st centuries (Figure 4-14).

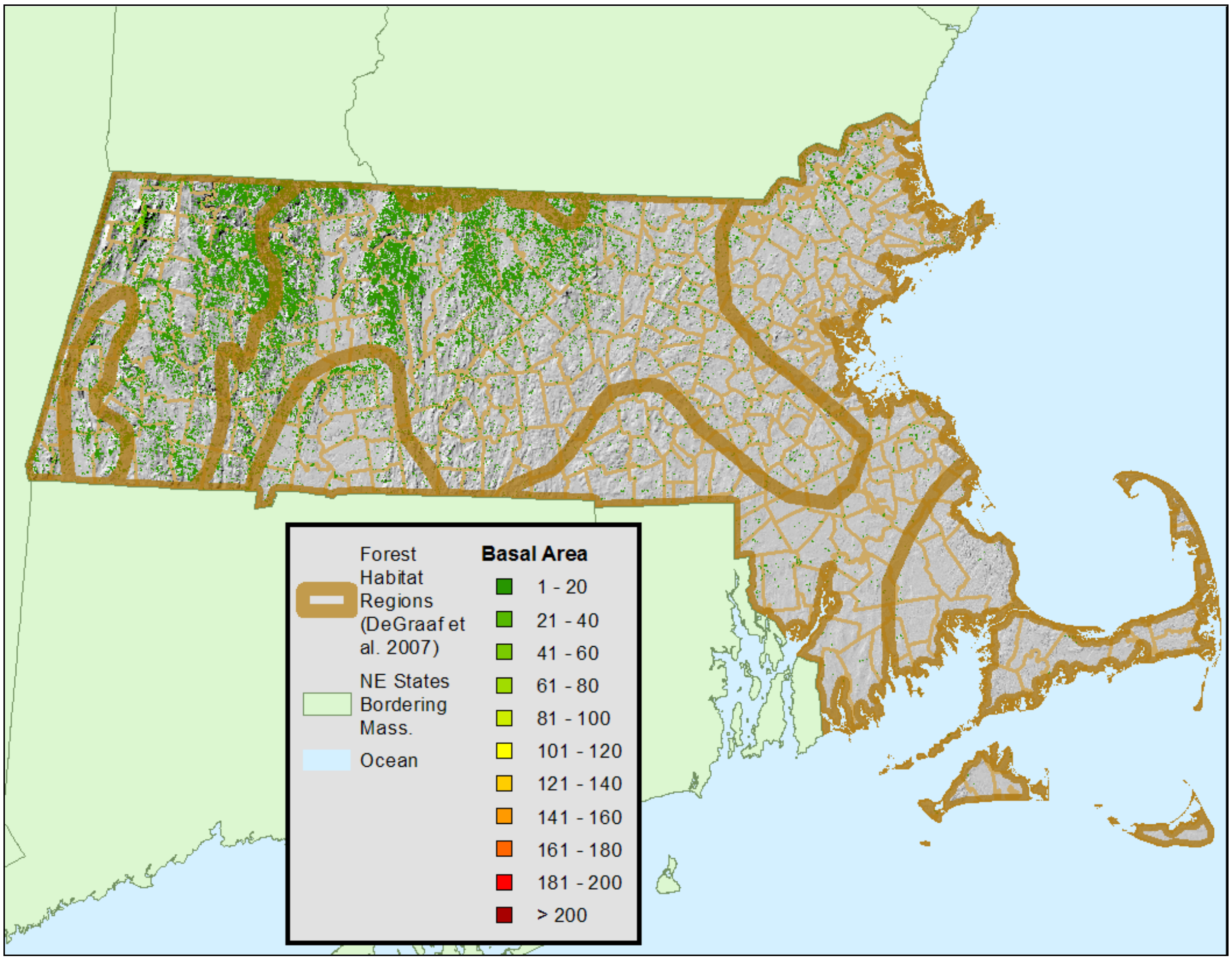


Figure 4-13. Occurrence of Paper and Gray Birch in Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

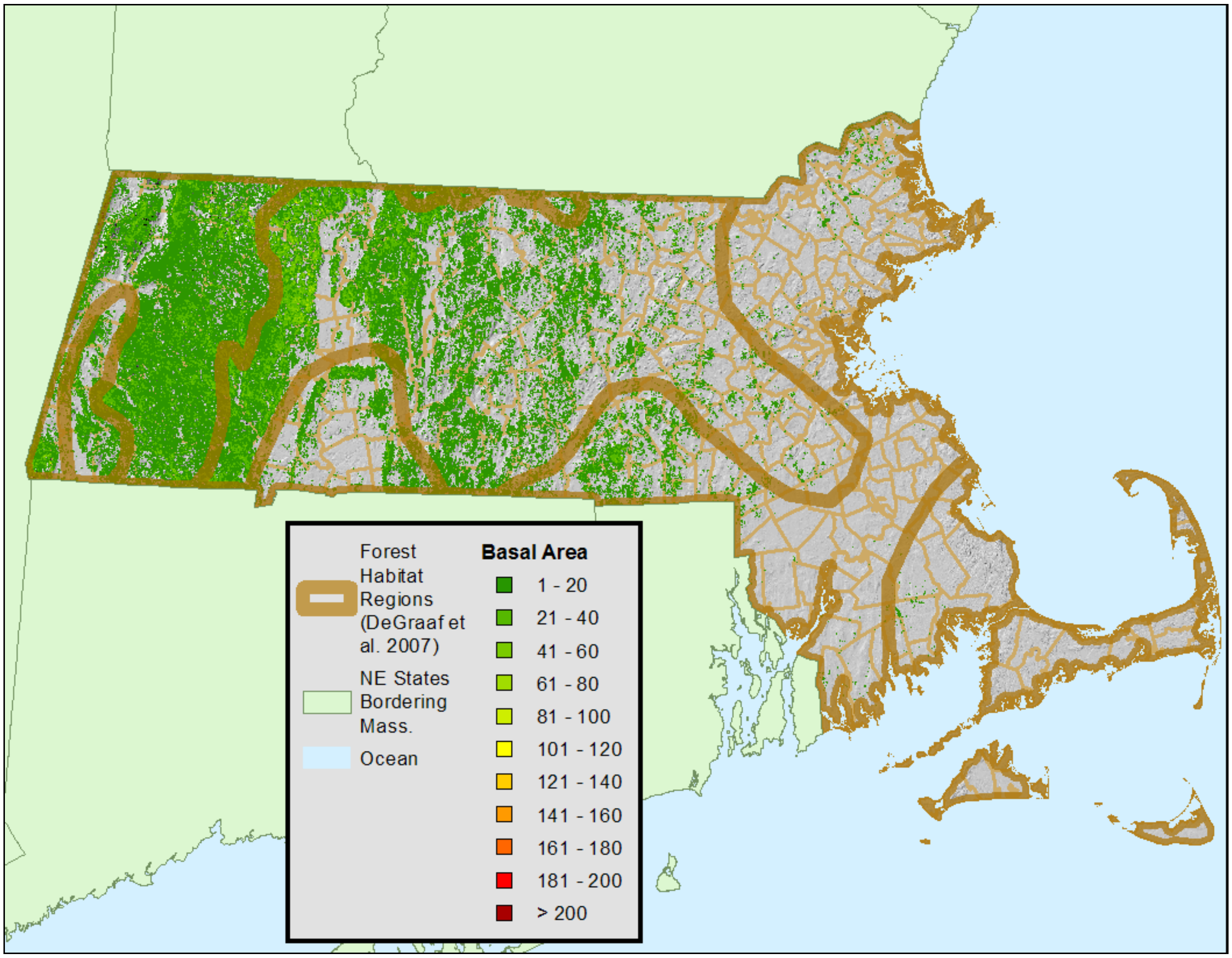


Figure 4-14. Occurrence of Yellow Birch and Black Birch in Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

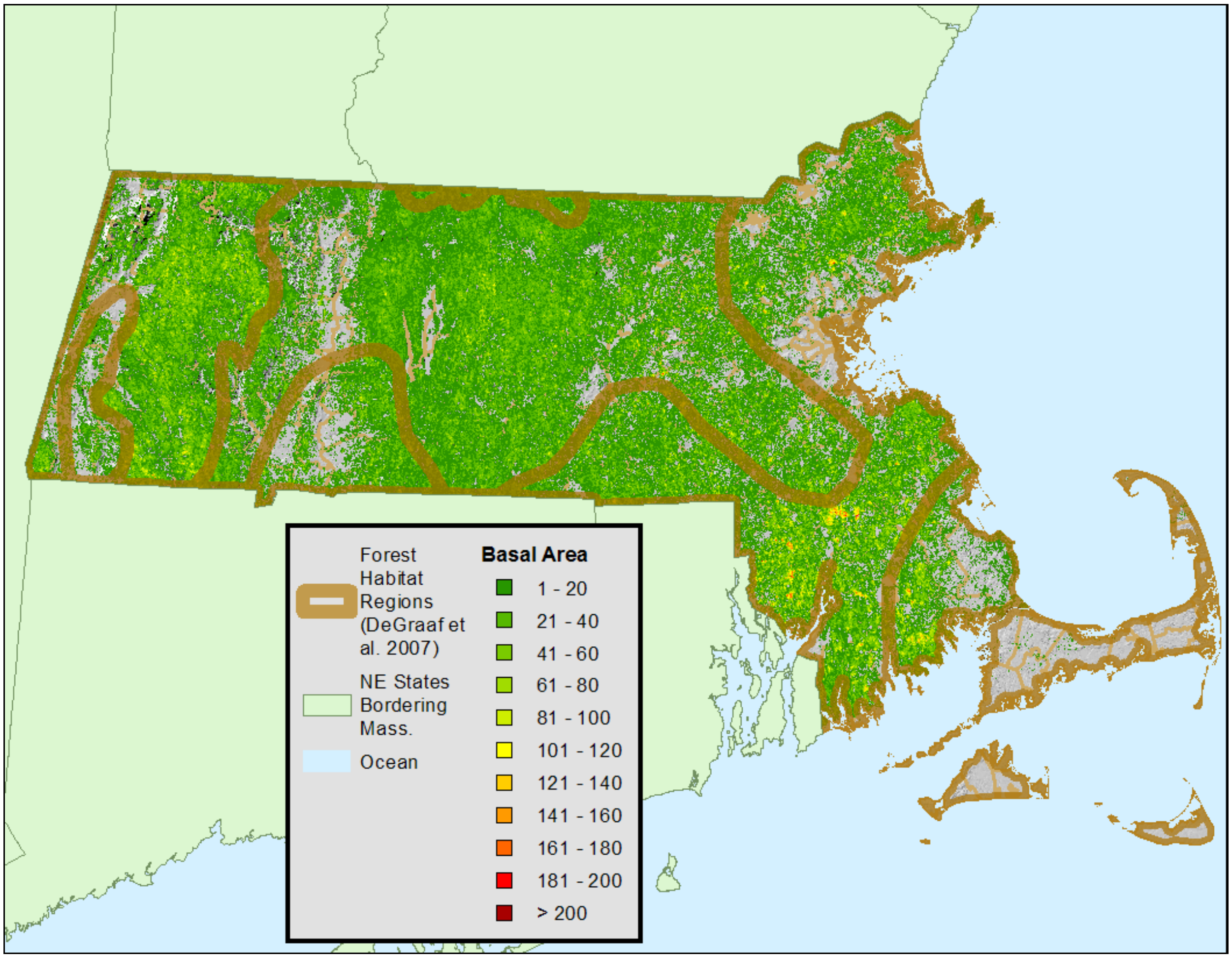


Figure 4-15. Occurrence of Red Maple in Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

Perhaps the best example of a species that has benefited from the long-term changes in human land-use in Massachusetts is Red Maple. An increasingly common component of today's transitional forest (Butler 2014), this is a species that was associated primarily with forested wetlands at the time of European settlement. Red Maple has exceedingly thin bark and does not tolerate fire. Following European farm abandonment in the late 19th century, a drastic decrease in agricultural and rural use of fire, and successful fire suppression efforts in the 20th century, Red Maple became an opportunistic occupier of upland forests throughout Massachusetts (Figure 4-15), germinating well both in forest understories with very little light and in abandoned open fields. Red Maple saplings that start in closed canopy forests are able to increase growth quickly after partial canopy openings from logging, disease, or wind events. Since Red Maple wood has historically been of lower economic value for timber, other species were preferentially harvested. All of these factors have resulted in today's situation where Red Maple stems outnumber those of any other tree species in Massachusetts (Butler 2014).

Heavier-seeded tree species like oak and hickory did not reestablish well in the early second-growth forest, but survived in the long run because individual oak and/or hickory trees were often retained within active pasture lands prior to agricultural abandonment to provide shade and food for livestock, and these relatively long-lived trees persisted for many decades following abandonment until conditions in the second-growth forest became more amenable for oak to regenerate successfully.

Oak is now common throughout Massachusetts forestlands, occurring in all areas of the state, except the highest elevations of the Northern Hardwoods-Spruce-Fir region (Figure 4-16). This is likely because after White Pine became the dominant tree species of the early second-growth forest, it created favorable conditions for Blue Jays to plant acorns. While we commonly associate squirrels and chipmunks with storing and burying acorns, these animals tend to remember where they put the acorns and often return to their cached food stores. Blue Jays, on the other hand, often plant acorns beneath pine forest and don't always return to reclaim their prize. Today, a forest stand dominated by White Pine is likely to regenerate to more hardwoods than pine if cut heavily, unless the stand occurs on dry, sandy soils that especially favor pine.

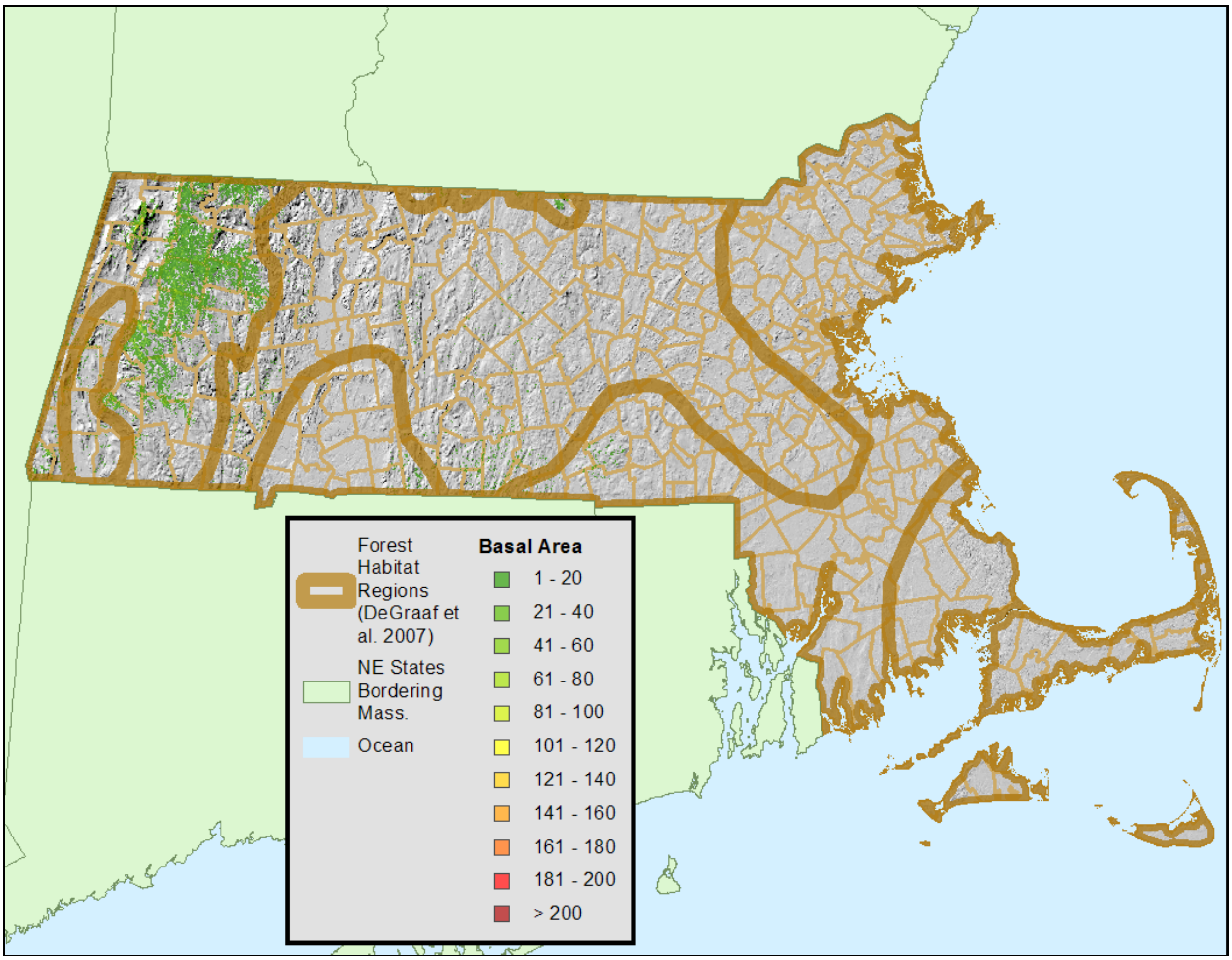


Figure 4-16. Occurrence of spruce and fir within the Northern Hardwoods-Spruce-Fir forest habitat.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

By 1985, White Pine trees accounted for the largest volume of growing stock trees. However, the most abundant tree in Massachusetts forestlands by number of stems was already Red Maple (Dickson and McAfee, 1988). Over the last three decades, this relationship has remained: Red Maple has maintained the lead in number of trees and White Pine is the second most numerous, but White Pine volume has grown to over 2 billion cubic feet of live tree volume compared to Red Maple's 1.4 billion cubic feet in 2013 (Butler 2014). Although Northern Red Oak is in a distant 7th place by number of trees, following just behind Eastern Hemlock (Figure 4-12), American Beech, Sweet (Black) Birch, and Sugar Maple stems, by volume oak is in 3rd place with nearly 1 billion cubic feet of live tree volume. These relative positions are likely an ephemeral condition, at least in the timeframe of forested ecosystems. Depending on relative species dynamics, changes in future climate, and patterns of human forest harvesting practices, a few centuries from now White Pine could cede dominance to oaks, Red Maple could add volume dominance to its already commanding numerical leadership, or some unsuspected dynamic could otherwise alter the composition of Massachusetts forests.

While the Transitional Forest we see today in Massachusetts combines elements of both the Northern Hardwood and Oak-Hickory forest types, it importantly does not contain all elements of those types. In particular, it is the shade-intolerant tree species typically associated with the Northern Hardwood Forest (those species that prefer to grow as seedlings in full sunlight) that are most common in today's Transitional Forest type. In particular, Black Cherry, White Ash, and Black Birch (Figure 4-14) are examples of northern hardwood species that became established in the open, sunlit conditions of the early second-growth forest. Ash and birch seeds are wind-disseminated and cherry is among the most prized of wildlife foods, so the fruits are consumed by a variety of birds and mammals, and the seed is eventually deposited far and wide as the animals travel. Conversely, keystone species of the Northern Hardwood Forest like American Beech, Sugar Maple, Yellow Birch, and Red Spruce are not especially abundant in today's Transitional Forest because seedlings of these species do not grow well in open sunlight; they much prefer a cool, shaded understory to begin their sylvan existence. Red Maple, a species well suited to regenerating in small gaps, does especially well by comparison.

Today's Transitional Forest offers wildlife habitat that is distinctly different from that of the pre-colonial forests, primarily due to the changes in mast species such as oaks, cherries, and beech. In habitats of the pre-colonial forest, oak occurred predominantly in the central hardwoods areas of the Eastern Broadleaf ecoregional province, and cherry occurred along with beech in the northern hardwoods areas of the New England-Adirondack ecoregional province (Figure 4-6). In the portions of Massachusetts formerly dominated by Northern Hardwood Forest that now support Transitional Forest (Figure 4-9), the effect of the landscape-wide loss of beechnut production due to the invasive beech-scale complex is dramatically reduced by its replacement with oak mast. The modern co-occurrence of oak and cherry, two highly utilized mast-tree genera, in the Transitional Forest that were formerly dominated by Central Hardwoods, provides a more consistent food resource over time than that provided in forests with just oak species present.

In Northern Hardwood Forests, oak is relatively uncommon, but oak is abundant in Transitional Forests. The cyclical outbreaks of the invasive, exotic Gypsy Moth from the late 1800s to the 1980s caused extensive oak mortality statewide, but such landscape-level impacts have been dampened over the past few decades by a combination of the adaptation of native mammals such as the White-footed Mouse to feed on Gypsy Moth larva at low insect densities and the emergence of a nuclear polyedrosis virus at high insect densities (Elkington et al. 1996).

Species of Greatest Conservation Need in Transition Hardwoods-White Pine Upland Forest

Seventy-four SGCN are assigned to the Transition Hardwoods-White Pine Upland Forest habitat (Table 4-9).

In Massachusetts, the Early Hairstreak butterfly is restricted to Berkshire and Franklin counties, where it inhabits Northern Hardwoods-Spruce-Fir and Transition Hardwoods-White Pine forest with a significant component of beech (*Fagus grandifolia*). As a larva, this species feeds on the flowers, developing fruits, and leaves of beech trees. Adult butterflies are typically observed either "puddling" (imbibing moisture) on damp ground or nectaring at flowers, in forest openings such as unpaved roads and field margins. Currently, the most significant threat to this species is probably the loss of beech trees to beech-bark disease, which occurs when bark damaged by the introduced beech-scale insect (*Cryptococcus fagisuga*) subsequently becomes infected with fungi (*Nectria* spp.).

In Massachusetts, the Orange Sallow moth occurs in Transition Hardwoods-White Pine forest and Central Hardwoods-White Pine forest, most frequently in upland forest dominated by oak trees. It is not so much a forest species as a forest-opening and -edge species, as the larvae feed on false foxgloves (*Aureolaria pedicularia* and *A. flava*). It is a good example of a species that benefits from fire, as both false foxgloves and the Orange Sallow moth thrive in oak woodland with a relatively open canopy as a result of fire.

Plant SGCN that may be found within the Transition Hardwoods–White Pine forest include the Violet Wood-sorrel, American Ginseng, Small-flowered Buttercup, Bristly Black Currant, Canadian Sanicle, Clustered Sanicle, Rand's Goldenrod, Shining Wedgescale, Crooked-stem Aster, Nodding Pogonia, Yellow Oak, and Downy Arrow-wood. Some of these species prefer the calcareous substrate, which is rare in Massachusetts; others prefer the beech-maple-birch forests and form mycorrhizal associations with trees in this forest type. Some of these species, although associated with this forest type, actually thrive in openings within this forest or under, at most, partial canopy; this includes Climbing Fumitory, Purple Giant Hyssop, Downy Agrimony, Upright False Bindweed, and the round-leaved orchids. Rich, Mesic Forest plant species are included under this forest type, including Climbing Fumitory, Smooth Rock-cress, Green Rock-cress, Hitchcock's Sedge, Devil's-bit, Purple Clematis, Northern Wild Comfrey and the lady's-slippers. Large-leaved Sandwort needs serpentine bedrock, which is located within this forest type in Western Massachusetts.

Table 4-9: Species of Greatest Conservation Need in Transition Hardwoods-White Pine Upland Forests

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Ambystoma jeffersonianum*	Jefferson Salamander
	Ambystoma laterale	Blue-Spotted Salamander
	Ambystoma opacum	Marbled Salamander
Reptiles	*Agkistrodon contortrix*	Northern Copperhead
	Coluber constrictor	North American Racer
	Crotalus horridus	Timber Rattlesnake
	Heterodon platirhinos	Eastern Hog-nosed Snake
	Pantherophis alleghaniensis	Eastern Ratsnake
	Terrapene carolina	Eastern Box Turtle
Birds	*Accipiter gentilis*	Northern Goshawk
	Antrostomus vociferus	Eastern Whip-poor-will
	Asio otus	Long-eared Owl
	Buteo platypterus	Broad-Winged Hawk
	Chaetura pelagica	Chimney Swift
	Haemorhous purpureus	Purple Finch
	Hylocichla mustelina	Wood Thrush
	Piranga olivacea	Scarlet Tanager
Mammals	*Alces americanus*	Moose
	Eptesicus fuscus	Big Brown Bat
	Lasionycteris noctivagans	Silver-haired Bat
	Lasiurus borealis	Eastern Red Bat
	Lasiurus cinereus	Hoary Bat
	Lynx rufus	Bobcat
	Myotis leibii	Small-footed Myotis
	Myotis lucifugus	Little Brown Myotis
	Myotis septentrionalis	Northern Myotis
	Perimyotis subflavus	Tricolored Bat
	Ursus americanus	Black Bear
Butterflies and Moths	*Pyrrhia aurantiago*	Orange Sallow
Plants	*Actaea racemosa*	Black Cohosh
	Adlumia fungosa	Climbing Fumitory
	Agrimonia pubescens	Hairy Agrimony
	Amelanchier bartramiana	Bartram's Shadbush
	Aplectrum hyemale	Putty-root
	Blephilia ciliata	Downy Wood-mint
	Boechera missouriensis	Green Rock-cress
	Calystegia spithamaea	Upright False Bindweed
	Carex backii	Back's Sedge
	Carex formosa	Handsome Sedge
	Carex glaucodea	Glaucescent Sedge
	Carex hitchcockiana	Hitchcock's Sedge
	Carex polymorpha	Variable Sedge
	Chamaelirium luteum	Devil's-bit
	Clematis occidentalis	Purple Clematis
	Corallorhiza odontorhiza	Autumn Coral-root
	Cynoglossum virginianum var. *boreale*	Northern Wild Comfrey
	Cyperus houghtonii	Houghton's Flatsedge
	Cypripedium arietinum	Ram's Head Lady's-slipper
	Cypripedium parviflorum	Yellow Lady's-slipper
	Desmodium cuspidatum	Large-bracted Tick-trefoil
	Doellingeria infirma	Cornel-leaved Aster
	Galearis spectabilis	Showy Orchid

Taxon Grouping	Scientific Name	Common Name
	Geum fragarioides	Barren Strawberry
	Goodyera repens	Dwarf Rattlesnake-plantain
	Hydrastis canadensis	Golden Seal
	Hydrophyllum canadense	Broad Waterleaf
	Isotria medeoloides	Small Whorled Pogonia
	Linnaea borealis ssp. *americana*	American Twinflower
	Liparis liliifolia	Lily-leaf Twayblade
	Lygodium palmatum	Climbing Fern
	Malaxis bayardii	Bayard's Adder's Mouth
	Milium effusum	Woodland-millet
	Morus rubra	Red Mulberry
	Orthilia secunda	One-sided Wintergreen
	Oxalis violacea	Violet Wood-sorrel
	Panax quinquefolius	American Ginseng
	Platanthera hookeri	Hooker’s Orchid
	Poa saltuensis ssp. *languida*	Drooping Speargrass
	Ranunculus micranthus	Small-flowered Buttercup
	Sanicula odorata	Clustered Sanicle
	Solidago simplex ssp. *randii* var. *monticola*	Rand's Goldenrod
	Sphenopholis nitida	Shining Wedgescale
	Symphyotrichum prenanthoides	Crooked-stem Aster
	Triphora trianthophora	Nodding Pogonia
	Viburnum rafinesquianum	Downy Arrow-wood

Northern Hardwoods-Spruce-Fir Upland Forest

Habitat Description

Even prior to European settlement and the ensuing changes in forests in Massachusetts (see the Transition Hardwoods-White Pine habitat description above for more details), Northern Hardwood-Spruce-Fir upland forest habitat in Massachusetts was limited to the upper elevations and latitudes of northwestern Massachusetts and far northern central Massachusetts (Figure 4-7). Human land-use patterns have further restricted this habitat, especially along the southern and eastern edges of these forest types, and there remain just over 600,000 forested acres in this type of upland forest habitat in Massachusetts (Table 4-7).

This general forest habitat type comprises a number of different forest vegetation communities, ranging from widely occurring communities such as Northern Hardwoods-Hemlock-White Pine Forest and Successional Northern Hardwood Forest to more geographically restricted communities such as High Elevation Spruce-Fir Forest/Woodland, Rich Mesic Forest Community, and Ridgetop Pitch Pine-Scrub Oak Community (Table 4-10). Most of these more restricted community types are limited by specific bedrock or soil conditions. For example, High Elevation Spruce-Fir Forest/Woodland occurs only at the very highest elevations in the state, predominantly along the top of the Berkshire Plateau from the town of Monroe south to the towns of Washington and Becket and east to the towns of Heath, Ashfield, and Goshen, and the more common Spruce-Fir-Northern Hardwoods Forest occurs at slightly lower elevations and where human land-use patterns have reduced the prevalence of spruce and fir on the higher elevations (Figure 4-16). The Calcareous Forest Seep community occurs only in areas that are both underlain by calcareous bedrock and where groundwater reaches the surface in a seep. Rich, Mesic Forest occurs primarily on the toe-slopes of some hills, where nutrients from soils derived from moderately calcareous bedrock translocate downslope and accumulation allows nutrient-rich soils to develop. The Ridgetop Pitch Pine-Scrub Oak Community occurs only along exposed ridgetops with slow soil accumulation.

These forests include many different combinations of tree species; however, the most common hardwoods include Sugar Maple, Red Maple, American Beech, White Ash, Black Cherry, Yellow Birch, Black Birch, and Paper Birch, and the most common softwood species include Eastern Hemlock, Red Spruce, Balsam Fir, and Eastern White Pine (FIDO, 2013). Some of these communities, especially in lower latitudes and elevations of the region, also include tree species typically found in other forest habitat regions. These include Northern Red Oak, Bitternut Hickory, and Pitch Pine.

The few remaining small areas of primary forest and other biologically mature forest in Massachusetts are predominantly in Northern Hardwoods-Spruce-Fir upland forest. Although there are no obligate old-growth species in the state, the habitat features of such forests (e.g., complex size distribution; vertical complexity; uneven-aged forest with scattered large trees, often with cavities; standing dead trees; and large woody material on the ground) are widely used by both vertebrate and invertebrate species. Much of the interior-forest habitat in Massachusetts also occurs in Northern Hardwoods-Spruce-Fir forests, providing habitat for forest-interior bird species and area-dependent mammals.

Table 4-10. Terrestrial forest natural communities occurring within Northern Hardwoods-Spruce-Fir Upland Forest.

Data from Swain and Kearsley (2015). SRANK (State Rank) ranges from S1 (Critically Imperiled in Massachusetts) to S5 (Secure in Massachusetts). Communities ranked S1-S3 (in bold) are considered Priority Natural Communities.

Natural Community Name	SRANK
Northern Hardwoods - Hemlock - White Pine Forest	S5
Successional Northern Hardwood Forest	S5
Successional White Pine Forest	S5
Chestnut Oak Forest / Woodland	S4
Dry, Rich Oak Forest / Woodland	S4
Forest Seep Community	S4
Red Oak - Sugar Maple Transition Forest	S4
Spruce - Fir - Northern Hardwoods Forest	S4
Rich, Mesic Forest Community	**S3**
Hickory - Hop Hornbeam Forest / Woodland	**S2**
Ridgetop Pitch Pine - Scrub Oak Community	**S2**
Calcareous Forest Seep Community	**S1**
High Elevation Spruce - Fir Forest / Woodland	**S1**
Yellow Oak Dry Calcareous Forest	**S1**

Species of Greatest Conservation Need in the Northern Hardwoods-Spruce-Fir Upland Forest

Sixty-one SGCN are assigned to the Northern Hardwoods-Spruce-Fire Upland Forest habitat (Table 4-11).

It is hard to overstate the wildlife value of beechnuts in the northern hardwood forest for species such as Black Bear. A recent study in neighboring New York showed that the 2-year reproductive pattern of Black Bears corresponded to the biannual beechnut masting cycle over the 40-year period studied (LaMere 2012).

Numerous bird species make primary use of Spruce-Fir or Fir forest habitats, including the Three-toed Woodpecker, Black-backed Woodpecker, Yellow-bellied Flycatcher, Gray Jay, Boreal Chickadee, Golden-crowned Kinglet, Ruby-crowned Kinglet, and Blackpoll Warbler. Other species that once relied on this habitat subtype no longer nest in the state, such as the Olive-sided Flycatcher.

In Massachusetts, the Early Hairstreak butterfly is restricted to Berkshire and Franklin counties, where it inhabits Northern Hardwoods-Spruce-Fir and Transition Hardwoods-White Pine forest with a significant component of beech (*Fagus grandifolia*). As a larva, this species feeds on the flowers, developing fruits, and leaves of beech trees. Adult butterflies are typically observed either "puddling" (imbibing moisture) on damp ground or nectaring at flowers in forest openings, such as unpaved roads and field margins. Currently, the most significant threat to this species is probably the loss of beech trees to beech bark disease, which occurs when bark damaged by the introduced beech scale insect (*Cryptococcus fagisuga*) subsequently is infected with fungi (*Nectria* spp.).

Several plant SGCN occur only in the Northern Hardwoods-Spruce-Fir Upland Forests. Many of these plants have only one or two populations in Massachusetts, such as Dwarf Rattlesnake Plantain, Black-fruited Woodrush, Braun's Holly-fern, and Large-leaved Goldenrod. These species prefer the higher elevations or cool shady ravines found within this forest type. Downy Agrimony, Bartram's Shadbush, Hairy Wood-mint, Smooth Rock-cress, Hitchcock's Sedge, Autumn Coral-root, Showy Orchid, Broad Waterleaf, American Twinflower, Hairy Honeysuckle, Large Round-leaved Orchid, and Round-leaved Orchid are other plant SWAP species that also prefer this forest type.

Table 4-11: Species of Greatest Conservation Need in Northern Hardwoods-Spruce-Fir Upland Forests

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Ambystoma jeffersonianum*	Jefferson Salamander
	Ambystoma laterale	Blue-Spotted Salamander
Reptiles	*Crotalus horridus*	Timber Rattlesnake
Birds	*Accipiter gentilis*	Northern Goshawk
	Buteo platypterus	Broad-Winged Hawk
	Chaetura pelagica	Chimney Swift
	Haemorhous purpureus	Purple Finch
	Hylocichla mustelina	Wood Thrush
	Mniotilta varia	Black-and-white Warbler
	Piranga olivacea	Scarlet Tanager
	Setophaga striata	Blackpoll Warbler
Mammals	*Alces americanus*	Moose
	Eptesicus fuscus	Big Brown Bat
	Glaucomys sabrinus	Northern Flying Squirrel
	Lasionycteris noctivagans	Silver-haired Bat
	Lasiurus borealis	Eastern Red Bat
	Lasiurus cinereus	Hoary Bat
	Lynx rufus	Bobcat
	Myotis leibii	Small-footed Myotis
	Myotis lucifugus	Little Brown Myotis
	Myotis septentrionalis	Northern Myotis
	Perimyotis subflavus	Tricolored Bat
	Ursus americanus	Black Bear
Butterflies and Moths	*Erora laeta*	Early Hairstreak
Plants	*Agastache scrophulariifolia*	Purple Giant Hyssop
	Blephilia hirsuta	Hairy Wood-mint
	Boechera laevigata	Smooth Rock-cress
	Carex castanea	Chestnut-colored Sedge
	Carex formosa	Handsome Sedge
	Carex hitchcockiana	Hitchcock's Sedge
	Chamaelirium luteum	Devil's-bit
	Clematis occidentalis	Purple Clematis
	Corallorhiza odontorhiza	Autumn Coral-root
	Cynoglossum virginianum var. *boreale*	Northern Wild Comfrey
	Cyperus houghtonii	Houghton's Flatsedge
	Cypripedium parviflorum	Yellow Lady's-slipper
	Desmodium cuspidatum	Large-bracted Tick-trefoil
	Galearis spectabilis	Showy Orchid
	Geum fragarioides	Barren Strawberry
	Goodyera repens	Dwarf Rattlesnake-plantain
	Hydrophyllum canadense	Broad Waterleaf
	Ilex montana	Big-leaved Winterberry
	Linnaea borealis ssp. *americana*	American Twinflower
	Lonicera hirsuta	Hairy Honeysuckle
	Luzula parviflora ssp. *melanocarpa*	Black-fruited Woodrush
	Milium effusum	Woodland-millet
	Moehringia macrophylla	Large-leaved Sandwort
	Orthilia secunda	One-sided Wintergreen
	Panax quinquefolius	American Ginseng
	Platanthera hookeri	Hooker’s Orchid
	Platanthera macrophylla	Large Round-leaved Orchid
	Platanthera orbiculata	Round-leaved Orchid

Taxon Grouping	Scientific Name	Common Name
	Polystichum braunii	Braun's Holly-fern
	Ribes lacustre	Bristly Black Currant
	Sanicula canadensis	Canadian Sanicle
	Sanicula odorata	Clustered Sanicle
	Solidago macrophylla	Large-leaved Goldenrod
	Sorbus decora	Northern Mountain-ash
	Symphyotrichum prenanthoides	Crooked-stem Aster
	Triphora trianthophora	Nodding Pogonia
	Viburnum rafinesquianum	Downy Arrow-wood

Central Hardwoods-White Pine Upland Forest

Habitat Description

The Central Hardwoods-White Pine habitat of Massachusetts is near the northern edge of over 100,000 square miles of that forest type, which stretches from Georgia to southwest coastal Maine. Also referred to as Appalachian Oak Forest or Central Hardwoods Forest, this forested habitat is dominated by species in the oak (Figure 4-17) and hickory (Figure 4-18) genera. In Massachusetts, Eastern White Pine is also a significant component of these forests (Figure 4-11), as reflected by Bromley's mapping of this area (Bromley 1935) as "White Pine Forest," as is the ubiquitous Red Maple (Figure 4-15). Although DeGraaf (2007) refers to this type as Central Hardwoods-Hemlock-White Pine, in Massachusetts Eastern Hemlock is only a minor component of this forest area (Figure 4-12).

As discussed in the section on Transition Hardwoods-White Pine, European settlement was largely responsible for the conversion of the presettlement oak forest to an agricultural landscape. Following farm abandonment and subsequent urbanization, the nearly complete loss of fire as a disturbance mechanism is likely a contributing factor to the increasing dominance of fire-intolerant species such as White Pine and Red Maple in the second-growth forest, and the decrease in regeneration of more fire-tolerant oaks and hickories.

Despite this gradual change, Central Hardwoods-White Pine upland forest habitat continues to support a number of oak-dominated natural communities (Table 4-12). In the most xeric areas and those with a continuing occurrence of fire, this habitat transitions into Pitch Pine-Oak habitat, and many natural community types are common to both habitats.

Table 4-12. Terrestrial forest natural communities occurring within Central Hardwoods-White Pine Upland Forest.

Data from Swain and Kearsley (2015). SRANK (State Rank) ranges from S1 (Critically Imperiled in Massachusetts) to S5 (Secure in Massachusetts). Communities ranked S1-S3 (in bold) are considered Priority Natural Communities.

Natural Community Name	SRANK
Mixed Oak Forest / Woodland	S5
Oak - Hemlock - White Pine Forest	S5
Successional Northern Hardwood Forest	S5
Successional White Pine Forest	S5
White Pine - Oak Forest	S5
Chestnut Oak Forest / Woodland	S4
Coastal Forest / Woodland	S4
Dry, Rich Oak Forest / Woodland	S4
Forest Seep Community	S4
Hemlock Forest	S4
Oak - Hickory Forest	S4
Pitch Pine - Oak Forest / Woodland	S4
Red Oak - Sugar Maple Transition Forest	S4
Black Oak - Scarlet Oak Woodland	**S3S4**
Open Oak Forest / Woodland	**S3**
Sugar Maple - Oak - Hickory Forest	**S3**
Hickory - Hop Hornbeam Forest / Woodland	**S2**
Maritime Forest / Woodland	**S2**
Pitch Pine - Scrub Oak Community	**S2**
Ridgetop Pitch Pine - Scrub Oak Community	**S2**
Calcareous Forest Seep Community	**S1**
Maritime Juniper Woodland / Shrubland	**S1**
Maritime Pitch Pine on Dunes	**S1**
Oak - Tulip Tree Forest	**S1**

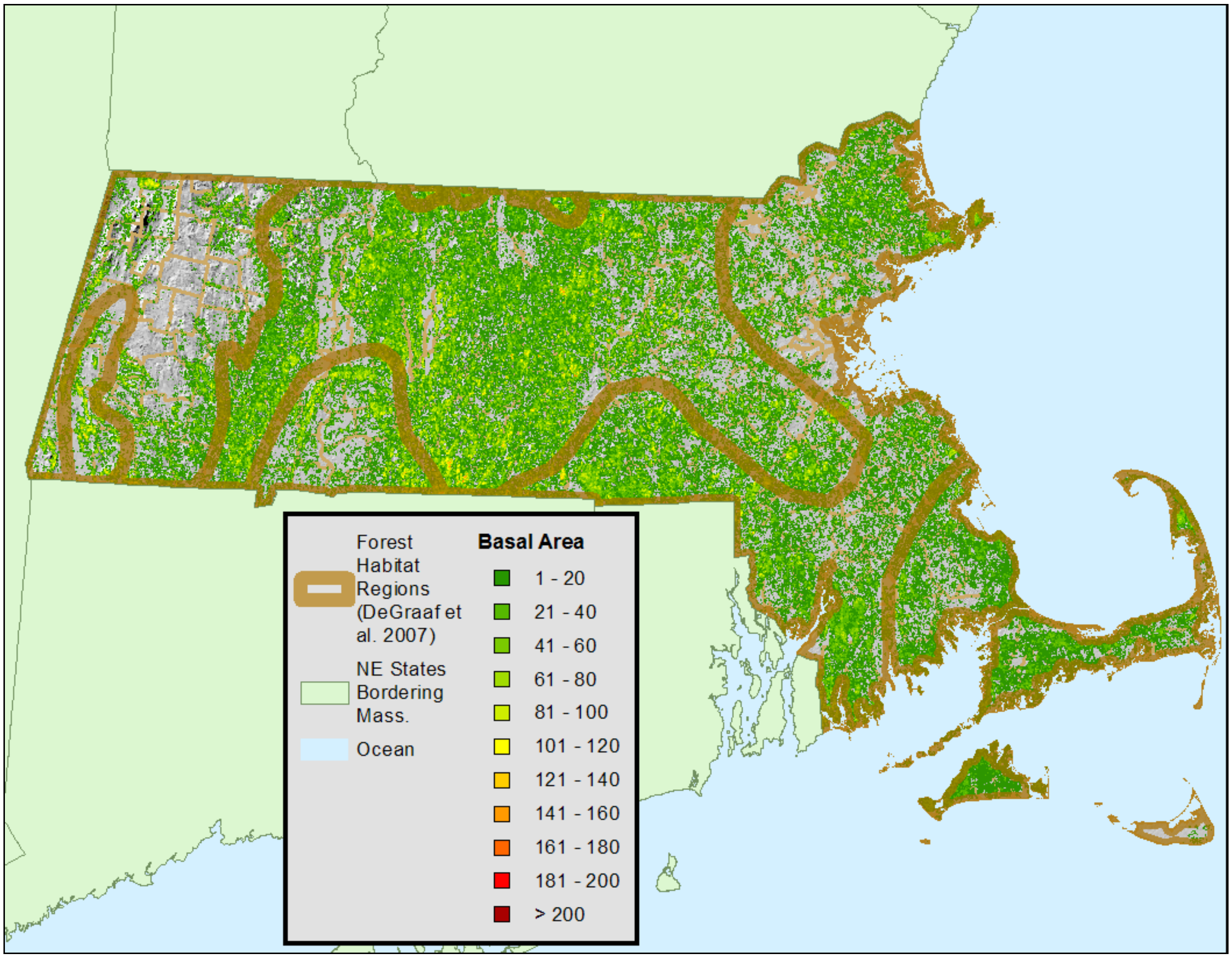


Figure 4-17. Occurrence of oak species (*Quercus* spp.) in comparison with the Central Hardwoods-White Pine forest habitat region of Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

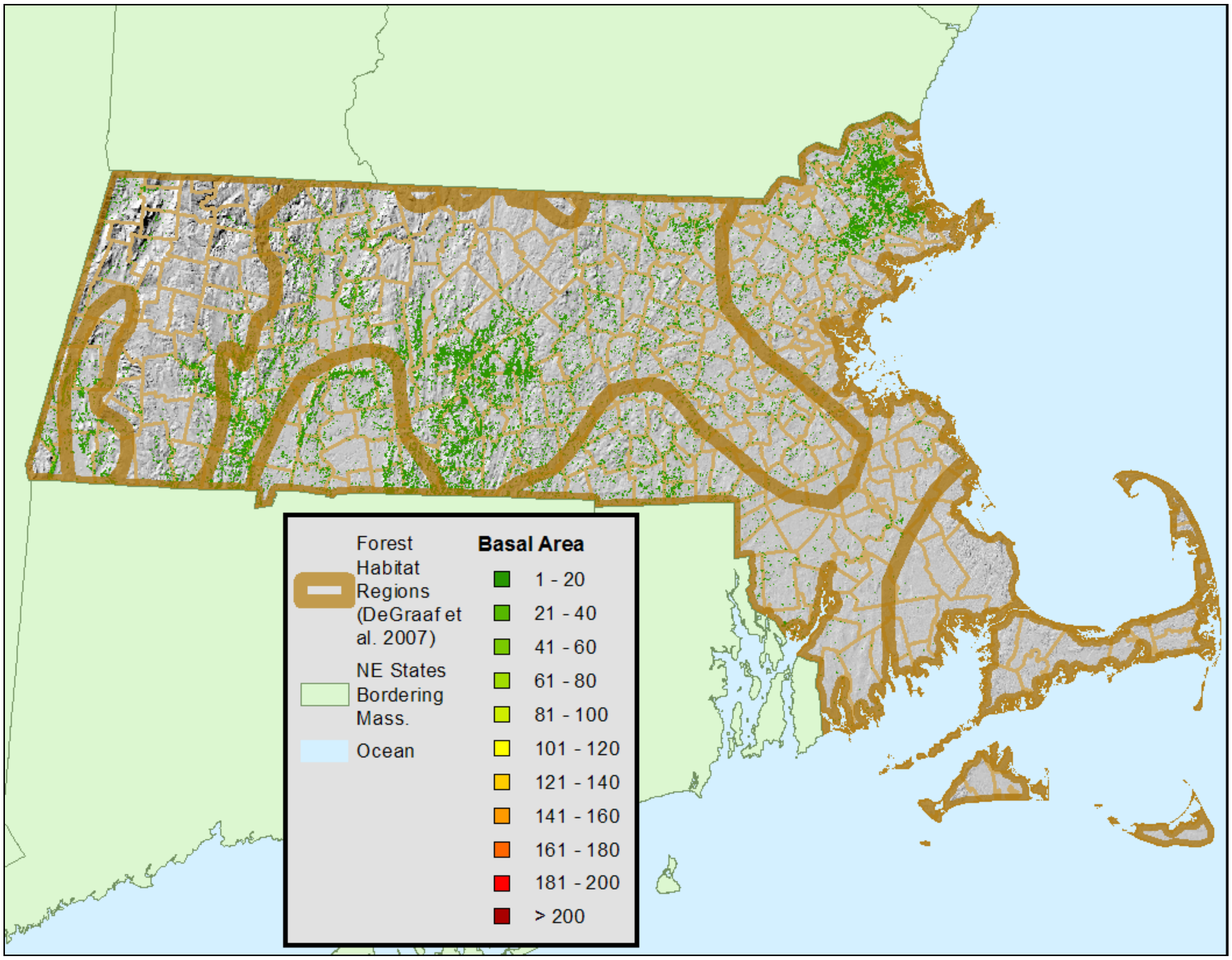


Figure 4-18. Occurrence of hickory species (*Carya* spp.) in comparison with the Central Hardwoods-White Pine forest habitat region of Massachusetts.

Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USGS Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

Species of Greatest Conservation Need in Central Hardwoods-White Pine Upland Forests

Sixty-six SGCN are assigned to the Central Hardwoods-White Pine Upland Forest habitat (Table 4-13).

In Massachusetts, the Orange Sallow moth occurs in Transition Hardwoods-White Pine forest and Central Hardwoods-White Pine forest, most frequently in upland forest dominated by oak trees. It is not so much a forest species as a forest-opening and edge species, as the larvae feed on false foxgloves (*Aureolaria pedicularia* and *A. flava*). It is a good example of a species that benefits from fire, as both false foxgloves and the Orange Sallow moth thrive in oak woodland with a relatively open canopy resulting from fire.

Small-flowered Buttercup is found growing on basalt or other mafic rock, usually under a sparse canopy. Yellow Lady's-slipper, Large-bracted Tick-trefoil, and Cornel-leaved Aster may also be found on nonacidic (circumneutral or alkaline) rocky slopes with partial shade. Climbing Fern was fairly common historically throughout the edge of wetlands in this forest type; however, it decreased dramatically due to collection, and despite what appears to be sufficient appropriate habitat, it has remained an uncommon species. Drooping Speargrass may be observed in this forest type, and the cause for its rarity is unknown, although it may be impacted by invasive species.

Table 4-13: Species of Greatest Conservation Need in Central Hardwoods-White Pine Upland Forests

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Ambystoma jeffersonianum*	Jefferson Salamander
	Ambystoma laterale	Blue-Spotted Salamander
	Ambystoma opacum	Marbled Salamander
	Scaphiopus holbrookii	Eastern Spadefoot
Reptiles	*Agkistrodon contortrix*	Northern Copperhead
	Carphophis amoenus	Eastern Wormsnake
	Coluber constrictor	North American Racer
	Crotalus horridus	Timber Rattlesnake
	Heterodon platirhinos	Eastern Hog-nosed Snake
	Pantherophis alleghaniensis	Eastern Ratsnake
	Terrapene carolina	Eastern Box Turtle
Birds	*Accipiter gentilis*	Northern Goshawk
	Antrostomus vociferus	Eastern Whip-poor-will
	Buteo platypterus	Broad-Winged Hawk
	Chaetura pelagica	Chimney Swift
	Haemorhous purpureus	Purple Finch
	Hylocichla mustelina	Wood Thrush
	Pipilo erythrophthalmus	Eastern Towhee
	Piranga olivacea	Scarlet Tanager
	Setophaga americana	Northern Parula
	Setophaga cerulea	Cerulean Warbler
	Toxostoma rufum	Brown Thrasher
Mammals	*Alces americanus*	Moose
	Eptesicus fuscus	Big Brown Bat
	Lasionycteris noctivagans	Silver-haired Bat
	Lasiurus borealis	Eastern Red Bat
	Lasiurus cinereus	Hoary Bat
	Myotis leibii	Small-footed Myotis
	Myotis lucifugus	Little Brown Myotis
	Myotis septentrionalis	Northern Myotis
	Perimyotis subflavus	Tricolored Bat
	Ursus americanus	Black Bear

Taxon Grouping	Scientific Name	Common Name
Butterflies and Moths	*Pyrrhia aurantiago*	Orange Sallow
Plants	*Adlumia fungosa*	Climbing Fumitory
	Agrimonia pubescens	Hairy Agrimony
	Aristida purpurascens	Purple Needlegrass
	Boechera laevigata	Smooth Rock-cress
	Boechera missouriensis	Green Rock-cress
	Calamagrostis pickeringii	Pickering’s Reedgrass
	Carex glaucodea	Glaucescent Sedge
	Carex gracilescens	Slender Woodland Sedge
	Carex polymorpha	Variable Sedge
	Clematis occidentalis	Purple Clematis
	Corallorhiza odontorhiza	Autumn Coral-root
	Crocanthemum dumosum	Bushy Rockrose
	Cyperus houghtonii	Houghton's Flatsedge
	Cypripedium arietinum	Ram's Head Lady's-slipper
	Cypripedium parviflorum	Yellow Lady's-slipper
	Desmodium cuspidatum	Large-bracted Tick-trefoil
	Dichanthelium ovale ssp. *pseudopubescens*	Commons’ Panic-grass
	Doellingeria infirma	Cornel-leaved Aster
	Isotria medeoloides	Small Whorled Pogonia
	Liparis liliifolia	Lily-leaf Twayblade
	Lygodium palmatum	Climbing Fern
	Malaxis bayardii	Bayard's Adder's Mouth
	Morus rubra	Red Mulberry
	Oxalis violacea	Violet Wood-sorrel
	Panax quinquefolius	American Ginseng
	Platanthera hookeri	Hooker’s Orchid
	Poa saltuensis ssp. *languida*	Drooping Speargrass
	Quercus muehlenbergii	Yellow Oak
	Ranunculus micranthus	Small-flowered Buttercup
	Silene caroliniana ssp. *pensylvanica*	Wild Pink
	Sphenopholis nitida	Shining Wedgescale
	Tipularia discolor	Cranefly Orchid

Pitch Pine-Oak Upland Forest

Habitat Description

The Pitch Pine-Oak forest habitat region contains approximately 250,000 acres (about a third of the total area) of forest and non-forest habitat, with the remaining area primarily developed. This habitat is dominated by the natural community types shown in Table 4-14. Some of these types also occur as refugia within the Transition Hardwoods-White Pine and Central Hardwoods-White Pine habitat regions. In addition, smaller areas of forest community types from those other habitat regions occur within the Pitch Pine-Oak region.

Pitch Pine-Oak Forest (PPO) applies to a broad suite of closely related, highly dynamic vegetation communities best described as a continuum (Table 4-14). There are an infinite number of combinations of scrub oaks, tree oaks (Figure 4-17), Pitch Pine (Figure 4-19), heaths, grasses ,and forbs all sharing some common denominators. Within the matrix PPO forest are large areas of Pitch Pine/Scrub Oak (PPSO), itself a system that provides a matrix of these various stages of succession that include patches of grasslands and heathlands that are part of the system. Coastal Plain Ponds tend to be in the same areas and are parts of the larger system, connected through the groundwater hydrology and temporary habitats along pond shores.

Pitch Pine-Oak communities (PPO) serve as primary habitats for populations of an extraordinary number of state-listed species. Only a small fraction of this acreage is receiving appropriate management and restoration, without which this suite of natural communities, and the diversity of rare and threatened species that depend on them, will inevitably disappear from the Commonwealth.

Pitch Pine-Oak communities occur on coarse sandy substrates that drain rapidly, or on ridgetops with shallow, droughty soil and exposed bedrock. PPO communities are associated primarily with the glacial moraines and outwash plains of southeastern Massachusetts, but inland occurrences were not infrequent historically. Inland occurrences tend to have developed on the large sandplains formed when periglacial rivers poured coarse sediments into glacial lakes, forming thick deltaic deposits. PPO communities are all disturbance-dependent and influenced by periodic fire, ice storms, tropical storms, insect irruptions, salt spray, land use history, and combinations of these and other factors.

Pitch Pine-Oak forest composition and architecture depends on the timing, frequency, severity, intensity, and type of disturbance to which it is exposed. For example, frequent disturbance can produce a community dominated by low, multi-stemmed Scrub Oak with sparse emergent Pitch Pines, or tree oaks with interspersed heath and grassy patches, or a Scrub Oak savanna. Due to constant exposure to wind and winter ice storms, vegetation of similar structure and composition is found on exposed ridgetops throughout the state. Reduction in disturbance frequency and intensity results in a more closed-canopy structure, where tree oaks and Pitch Pine are dominant, though Scrub Oak, ericads (huckleberry and blueberry species), and occasional grass patches remain. Another phase in the continuum is composed of tree oaks over a shrub layer dominated by Black Huckleberry. Land-use history, particularly logging, charcoaling, and agriculture, has profoundly influenced PPO systems. Recent studies have revealed that past agricultural plowing often results, even after a hundred years, in a community typified by a reduced diversity of ericads under a dense canopy of Pitch Pine, with sparse scrub and tree oaks. Unplowed areas of PPO support resprouting tree and Scrub Oak individuals, whose below-ground components are hundreds of years old.

The most important result of the PPO continuum is that patches of all vegetation sub-types are important in maintaining a diverse assemblage of rare invertebrate and vertebrate species. A simplified expression to represent the dynamism of the spectrum of PPO communities is:

> Disturbance diversity = Habitat heterogeneity = Diversity of plant and animal species.

Some phases of the PPO continuum include patches with sparsely vegetated mineral soils resulting from severe wildfires that consumed all organic matter. These patches are important to some of our rarest invertebrates, but these conditions cannot be attained through the application of safe, low-severity prescribed burns. Light soil scarification can provide a surrogate for severe burns, but must be done judiciously to preserve areas of important lichens and mycorrhizal fungi present in the surface soils of these communities.

Invariably, Pitch Pine-Oak systems occur on glacial deposits that contain important aquifers supplying millions of gallons of clean freshwater to neighboring towns. This feature may serve to offset a generally negative public attitude toward PPO systems, which are often perceived as barrens or wasteland, due to poor soils for agriculture or forestry.

Table 4-14. Terrestrial forest and non-forest natural communities in the Pitch Pine/Scrub Oak continuum.

Data from Swain and Kearsley (2015). SRANK (State Rank) ranges from S1 (Critically Imperiled in Massachusetts) to S5 (Secure in Massachusetts). Communities ranked S1-S3 (in bold) are considered Priority Natural Communities.

Natural Community Name	SRANK
Mixed Oak Forest / Woodland	S5
Coastal Forest / Woodland	S4
Pitch Pine - Oak Forest / Woodland	S4
Black Oak - Scarlet Oak Woodland	**S3S4**
Maritime Forest / Woodland	**S2**
Pitch Pine - Scrub Oak Community	**S2**
Maritime Juniper Woodland / Shrubland	**S1**
Maritime Pitch Pine on Dunes	**S1**
Maritime Beach Strand Community	**S3**
Maritime Dune Community	**S3**
Maritime Shrubland Community	**S3**
Maritime Erosional Cliff Community	**S2**
Maritime Rock Cliff Community	**S2**
Scrub Oak Shrubland	**S2**
Sandplain Grassland	**S1**
Sandplain Heathland	**S1**

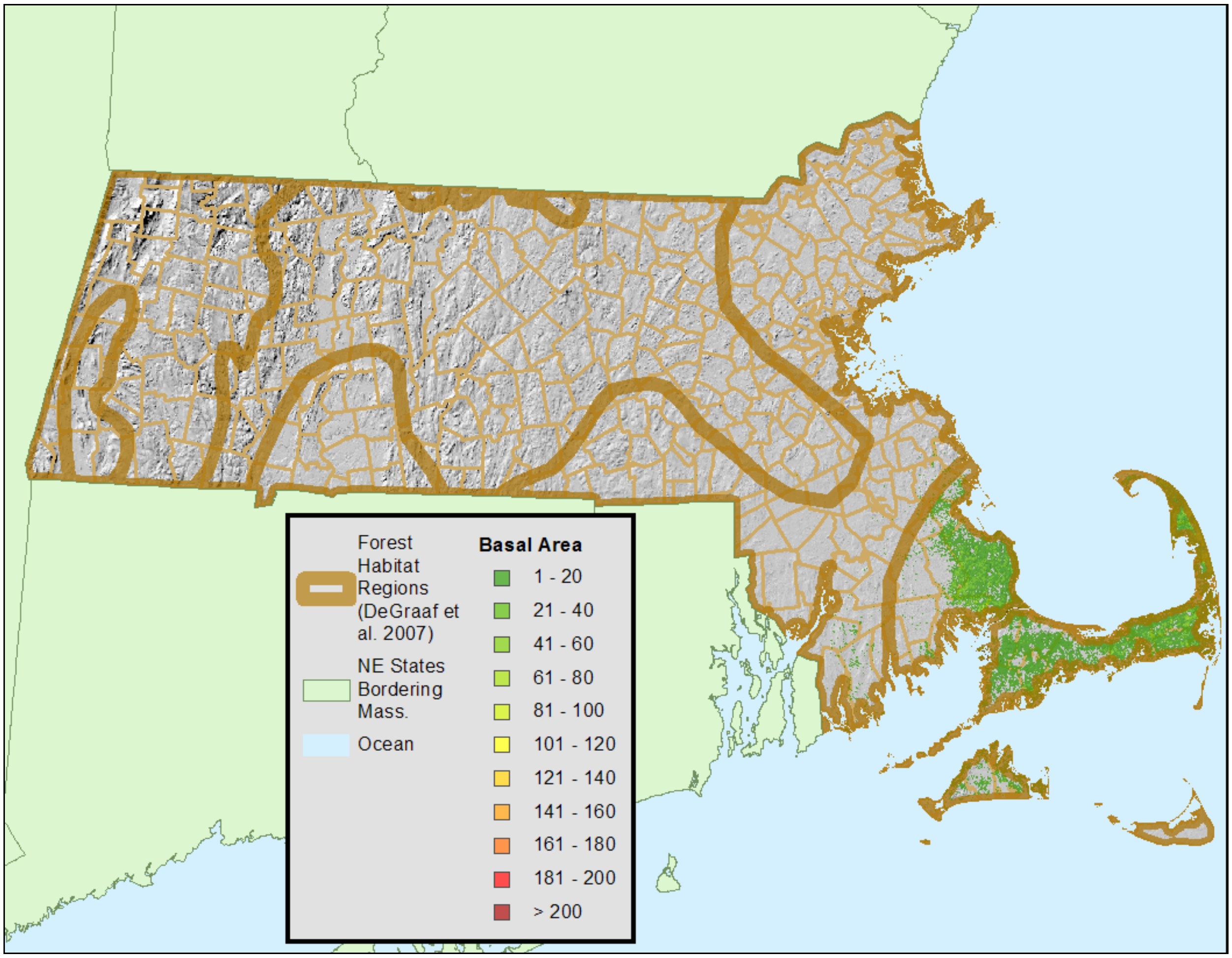


Figure 4-19. Occurrence of Pitch Pine trees within the Pitch Pine-Oak forest habitat of Massachusetts.

Pitch Pine elsewhere in Massachusetts is not shown. Forest regions adapted from DeGraaf et al. 2007. Tree occurrence data from USDA Individual Tree Species Parameter Maps (http://foresthealth.fs.usda.gov/portal, retrieved 2/10/2015).

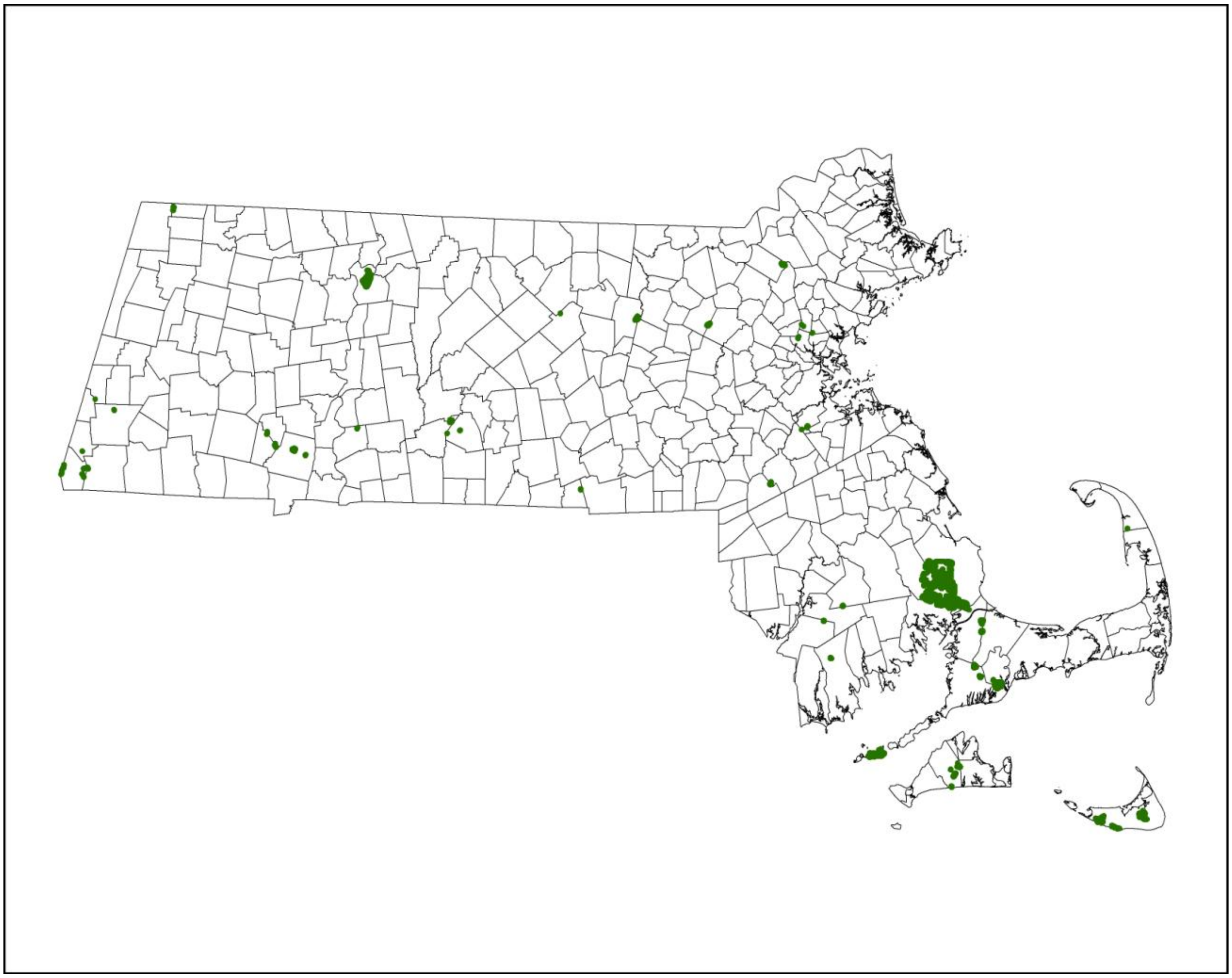


Figure 4-20: Locations of Pitch Pine/Scrub Oak Sites and Species in Massachusetts.

Data from NHESP database.

Species of Greatest Conservation Need in Pitch Pine-Oak Upland Forests

Forty-six SGCN are assigned to the Pitch Pine-Oak Upland Forest habitat (Table 4-15).

As can be seen from the table below, many rare Lepidoptera that are SWAP species depend on PPO systems for habitat, and many of these are restricted to Pitch Pine/Scrub Oak (PPSO) communities in particular. Few of these moth and butterfly species inhabit all community types within PPSO; many are specialists found in a particular microhabitat, i.e., frost barrens, river corridors, or closed-canopy forest stands. In addition, the caterpillars of many of these species are specialized in larval host plant use, consuming only one or a few closely related species of plants. Scrub Oak (*Quercus ilicifolia*) and lowbush blueberries (*Vaccinium angustifolium* and *V. pallidum*) are particularly important, as many rare PPSO Lepidoptera specialize on these plants. Other larval host plants used by rare PPSO moths and butterflies include other species of oaks (*Quercus* spp.), huckleberries (*Gaylussacia* spp.), Pitch Pine (*Pinus rigida*), Wild Indigo (*Baptisia tinctoria*), Wild Lupine (*Lupinus perennis*), New Jersey Tea (*Ceanothus americanus*), and Bayberry (*Morella pensylvanica*). Thus, to maintain populations of these species over time, it is necessary to maintain large areas of PPO systems, in various stages of responding to various kinds and severities of disturbance.

A number of vertebrates also use PPO communities, probably because of the open habitat structure provided, although no surviving vertebrate species in Massachusetts depends exclusively on PPO habitat. Thus, such early-successional birds as Prairie Warbler, Eastern Towhee, and Brown Thrasher can be found in both PPO and young forest/shrubland habitats. PPO systems that are particularly open, such as PPSO frost barrens, can support state-listed birds such as Vesper Sparrow and Northern Harrier. In other cases, the type of soil in PPO systems is the primary reason certain SWAP species occur there. For example, the Eastern Spadefoot requires loose, friable soils in which to burrow. Although the relatively open, patchy nature of the vegetation community in PPO systems is also considered beneficial to the Eastern Spadefoot, the sandy soils are a prerequisite to its use of the habitat.

The plant species found in PPO habitat are mostly specialists that grow in open, dry, sandy soil, and require disturbance such as fire to prevent overshading by trees. One exception is Pickering's Reedgrass, which is found in frost bottoms where soil moisture content is higher. Because PPO habitats are found most frequently in southeastern Massachusetts (Plymouth County, Cape Cod, and the offshore Islands), the rare plants associated with these habitats are typically found in the southeastern portion of the state as well. Houghton's Flatsedge is an exception; while it is found in dry, open conditions, it often occurs away from the coast.

Table 4-15. Species of Greatest Conservation Need in Pitch Pine-Oak Upland Forests

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Scaphiopus holbrookii*	Eastern Spadefoot
Reptiles	*Coluber constrictor*	North American Racer
	Heterodon platirhinos	Eastern Hog-nosed Snake
	Terrapene carolina	Eastern Box Turtle
Birds	*Antrostomus vociferus*	Whip-poor-will
	Asio otus	Long-eared Owl
	Circus cyaneus	Northern Harrier
	Colinus virginianus	Northern Bobwhite
	Pipilo erythrophthalmus	Eastern Towhee
	Pooecetes gramineus	Vesper Sparrow
	Setophaga americana	Northern Parula
	Setophaga discolor	Prairie Warbler
	Toxostoma rufum	Brown Thrasher
Mammals	*Sylvilagus transitionalis*	New England Cottontail
Beetles	*Cicindela patruela*	Barrens Tiger Beetle
	Nicrophorus americanus	American Burying Beetle
Lepidoptera	*Abagrotis nefascia*	Coastal Heathland Cutworm
	Acronicta albarufa	Barrens Dagger Moth
	Apodrepanulatrix liberaria	New Jersey Tea Inchworm
	Callophrys irus	Frosted Elfin
	Catocala herodias gerhardi	Herodias Underwing
	Chaetaglaea cerata	Waxed Sallow
	Cicinnus melsheimeri	Melsheimer’s Sack-bearer
	Cingilia catenaria	Chain-dotted Geometer
	Eacles imperialis	Imperial Moth
	Erynnis persius persius	Persius Duskywing
	Euchlaena madusaria	Scrub Euchlaena
	Hemaris gracilis	Slender Clearwing
	Hemileuca maia	Buck Moth
	Heterocampa varia	Sandplain Heterocampa
	Hypomecis buchholzaria	Buchholz’s Gray
	Lycia rachelae	Twilight Moth
	Lycia ypsilon	Woolly Gray
	Metarranthis apiciaria	Barrens Metarranthis
	Psectraglaea carnosa	Pink Sallow
	Ptichodis bistrigata	Southern Ptichodis
	Speranza exonerata	Pine Barrens Speranza
	Stenoporpia polygrammaria	Faded Gray
	Zale lunifera	Pine Barrens Zale
	Zanclognatha martha	Pine Barrens Zanclognatha
Plants	*Aristida purpurascens*	Purple Needlegrass
	Calamagrostis pickeringii	Pickering’s Reedgrass
	Corema conradii	Broom Crowberry
	Crocanthemum dumosum	Bushy Rockrose
	Cyperus houghtonii	Houghton's Flatsedge
	Dichanthelium ovale ssp. *pseudopubescens*	Commons’ Panic-grass
	Malaxis bayardii	Bayard's Adder's Mouth

Threats to Upland Forest Habitats

IUCN Threat 1: Residential and Commercial Development

According to the U.S. Census Bureau, between 1980 and 1990, the population of Massachusetts grew 4.9%; between 1990 and 2000, 5.5%; between 2000 and 2010, 3.1%; and between 2010 and 2014, 3.0%. This steady increase in the population of the state since 1980 has resulted in extensive conversion of upland forest for residential and commercial development. Nearly 50,000 acres of forest were converted to developed land, agricultural use, or other open land in Massachusetts between 2005 and 2013, varying in annual area converted between 20,000 acres in 2005 and about 5,000 acres in 2012 (Lautzenheiser et al. 2014).

As described in the section on use of biological resources below, non-forestry land clearing and other non-wood-products operations accounted for 12 million cubic feet of live tree removals in 2013 (Butler 2014). Using estimates of total live tree volume per acre of forest land from Butler (2014), the 2013 non-forestry removals of 12 million cubic feet would translate to about 4,400 acres of forest land converted to non-forest in 2013, which is consistent with the estimates of forest conversion from Lautzenheiser et al. (2014).

Forest cutting associated with conversion of forest to development can result in loss of shade and stability for small and large streams and rivers, thereby increasing siltation, erosion, and water temperature. This contributes directly to the decline of the habitats and Species of Greatest Conservation Need in these watercourses.

Furthermore, an increase in development brings an increase in the abundance of native and nonnative mesopredators. Raccoons, opossums, skunks, and domestic cats occur in greater numbers bordering development, thereby increasing predation on nests of turtles and birds such as the Eastern Whip-poor-will, Eastern Towhee, and Vesper Sparrow. Fragmentation in developed landscapes can also pose a threat to foraging behavior and dispersal for species such as the New England Cottontail, which is vulnerable to increased predation and loss of body mass in small habitat patches without escape cover, as compared to large habitat patches with dense shrub cover (Brown and Litvaitis 1995; Smith and Litvaitis 2000).

As Northern Hardwood-Spruce-Fir provides habitat for several species that require large areas of interior forest, the current highly dispersed development pattern in the region threatens habitat for those area-dependent interior forest species (e.g., Bobcat, Scarlet Tanager, Black-throated Green Warbler, Wood Thrush). These development patterns are typified by zoning bylaws requiring large lot sizes and extensive road frontages, and are associated with road rebuilding and lot clearing activities that fragment this habitat.

Pitch Pine-Oak (PPO) forests, and Pitch Pine/Scrub Oak (PPSO) habitats in particular, are severely threatened by both development and the suppression of fire. Much PPSO habitat has flat, easily-developed topography and occurs in coastal locations, making such areas very desirable for development. These same areas often overlay aquifers with an abundance of easily extracted groundwater. Large areas that historically supported PPSO communities have already been lost to development and habitat fragmentation. Fire exclusion practices have resulted in dense development in areas with highly flammable vegetation. This is not only a public safety hazard; the use of prescribed fire as a habitat management tool becomes increasingly difficult as the landscape becomes increasingly fragmented by development.

There are several species of butterflies and moths that depend on PPSO habitats, and some of these Lepidoptera require a large acreage of Scrub Oak barrens to have enough larval food plants or successional stages to support their populations. Small populations of both plants and animals have reduced genetic variability, and thus reduced ability to respond to changes in the environment. Populations that are already stressed may not recover from losing a generation of adults, such as occurs after spraying for Gypsy Moths or mosquitoes, which reduces populations of all species of adult butterflies and moths.

In addition to directly reducing the amount of PPSO habitat available to species of conservation concern, residential and commercial development fragments habitat, adversely impacting area-sensitive species as large, contiguous tracts of habitat are reduced to small, isolated patches. This also creates impediments and barriers to movement for some species. Roads, curbing, buildings, fences, and other structures impede movement of the Eastern Box Turtle and other ground-dwelling species. Especially at high density, such barriers may disrupt important metapopulation dynamics.

IUCN Threat 2: Agriculture and Aquaculture
As more attention is paid by environmental planners to issues of regional food production proposals are being made to more than triple the land area in New England devoted to crops and livestock (Donahue et al. 2014), primarily by converting back to agriculture the young forests now growing on fields and pastures abandoned since 1945. This vision aims for 70% forest cover in New England, "at least 50% in southern New England and at least 80% in northern New England." As shown in Table 4-7 and Jin (2013), Massachusetts was already down to just over 50% forested in 2011. Any increase in agricultural land in Massachusetts for regional food production will likely result in a decrease in wildlife habitat, including upland forest, as it is unlikely that land already devoted to residential, commercial, or industrial development will be converted to farms.

The types and longevity of agricultural practices in the past have resulted in various impacts to former upland forest, and have influenced the types of upland forest that developed after agricultural abandonment and forest regrowth. Any future clearing of forests for agriculture will similarly impact future forests, assuming that such agricultural uses are ever reduced. In addition to the impacts described above in the section on transitional forests, modern forest conversion to agriculture often results in dramatic changes to soil structure. For example, the tilling and addition of lime and fertilizer practiced in most agricultural practices are incompatible with the dry, sandy, nutrient-poor soils necessary to support Pitch Pine-Oak natural communities.

Forestry operations, although defined as agriculture in Massachusetts, are described below in the section on Biological Resource Use.

IUCN Threat 3: Energy Production and Mining
Threats from energy production vary widely across Massachusetts forest habitat types. Although some solar energy projects occur on former agricultural or brownfields land, forest clearing and conversion for industrial-scale photovoltaic projects is already occurring across Massachusetts, and is likely to continue. Road building and clearing for commercial wind-to-electricity projects affect Northern Hardwoods-Spruce-Fir forests, with fragmentation of interior forest habitat being a major impact.

Mining impacts are possible throughout the state; however, larger sand and gravel mining is most common in Pitch Pine-Oak habitat where sandy soils are most common. These operations can fragment PPO habitat in much the same way as residential and commercial development, in some cases disrupting or impeding animal movement patterns. Sand and gravel extraction in PPO forest and PPSO habitat change both topography and substrate, strongly affecting both future vegetation and the animal and plant species that can survive in an area.

IUCN Threat 4: Transportation and Service Corridors
Transportation and service corridors (e.g., roads, highways, railways) often act as physical barriers to movement and/or sources of adult and juvenile mortality for amphibians and reptiles (e.g., Eastern Spadefoot, Eastern Box Turtle, Eastern Hog-nosed Snake). Reproductive strategies of some species (especially Eastern Box Turtle) are based on high annual adult survivorship, and so road mortality is a significant threat to their local populations.

In Massachusetts, analysis of 272 road-kill rabbit carcasses collected between 2009 and 2013 from locations where New England Cottontail and the introduced Eastern Cottontail both occur resulted in 247 Eastern Cottontails and only 18 New England Cottontails. The remaining were either Snowshoe Hare or unidentified. It is unknown if New England Cottontail avoid crossing roads to forage in or disperse to suitable habitat. In contrast, shrubby cover within utility corridors along powerlines and pipelines may serve to facilitate dispersal of New England Cottontail.

Massachusetts has numerous existing electrical and pipeline service corridors, most of which traverse upland forest habitat. As of 2015, there are several proposals for additional natural gas pipelines traversing various portions of Massachusetts. Where construction, expansion, and maintenance of such service corridors involves clearing forests, there is not only the direct reduction in upland forest habitat acres, but also the potential for further impacting adjacent forest habitat through the fragmentation of interior forest habitats, especially in Northern Hardwood-Spruce-Fir forests. These service corridors and their associated access roads are also used by permitted or unpermitted off-highway vehicles for access to more remote forested areas. This additional motor vehicle use increases the disturbance footprint dramatically, and further reduces available interior forest habitat.

IUCN Threat 5: Biological Resource Use
In 2013, approximately 32 million cubic feet of live trees were harvested and used for wood products on forestland in Massachusetts, with 26 million cubic feet of that harvested from timberland (Butler 2014) and the remaining 6 million cubic feet harvested from non-timber forestland, including the commercial use of trees resulting from land clearing for buildings. An additional 6 million cubic feet of live trees were removed during activities such as land-clearing for building and were not used for wood products. Timberland is defined as “forest land that is producing or is capable of producing crops of industrial wood,” whereas forestland also includes transition areas adjacent to non-forestland such as developed areas (Oswalt 2015). Thus, forestry accounts for 26 million cubic feet of live tree removals each year, with 12 million cubic feet being removed in non-forestry land-clearing operations.

Removal of tree biomass is not in and of itself a threat to upland forest habitat. Such removals generally result in relatively short-term openings in forest canopy. Larger openings may result in the creation of young-forest habitat; even this regenerates to upland forest habitat within a few decades. However, certain forest-cutting practices represent threats to particular upland forest habitat types.

Forest cutting in this region of Massachusetts is often practiced as short-term income harvests involving removal of high-grade trees. These extractive cutting practices focus on removal of species and individuals of high economic value (e.g., well-formed stems of Black Cherry, Sugar Maple, and Red Spruce) and retention of species and individuals of lower economic value (e.g., poorly-formed stems, American Beech, Red Maple). The result over multiple cutting cycles across a landscape of Northern Hardwoods-Spruce-Fir forests is a gradual transition towards forest compositions more similar to the Transition Hardwoods-White Pine habitat type.

Forest-cutting practices in Central Hardwood-White Pine Habitats in Massachusetts typically involve partial overstory removal that is generally not favorable to regeneration of oak. Operations commonly remove about one-third (2.1-2.2 mbf per acre [DCR 2005]) of the approximately 6.2 total mbf per acre (Alerich 2000), and thus do not adequately open the forest canopy to promote oak regeneration. In much of the northeastern U.S., oak is not regenerating successfully on mesic sites that are otherwise amenable, and oak is gradually being replaced by more shade-tolerant tree species such as Red Maple and Black Birch (Lorimer 1993; Healy, et al. 1997). This trend is evident in Massachusetts, where the total area dominated by oak forest declined from about 35% to about 28% between 1985 and 1998 (Alerich 2000).

Extractive cutting as described above in Northern Hardwoods-Spruce-Fir habitats also occurs in Central Hardwood-White Pine habitats, with oak species being preferentially harvested. As in Northern Hardwoods-Spruce-Fir, this type of cutting tends to favor transitional forest types over Central Hardwood-White Pine habitat.

Pitch Pine-Oak systems that occur on private lands are subject to timber-harvesting (logging) practices that may attempt to convert stands dominated by Pitch Pine to other tree species that are more economically valuable. At sites where wildfire has been excluded for many years, such stand conversion is feasible. In addition, logging often introduces nonnative invasive plants and/or creates conditions (e.g., soil disturbance, increased light) that facilitate their proliferation. In Massachusetts, there are no regulations requiring landowners to control the spread of nonnative invasive plants following logging operations on their lands.

Forest management for pulp wood or timber production in the southeastern part of Massachusetts often results in conversion of Pitch Pine-Oak habitat to stands dominated by White Pine. This changes plant species composition not only in the overstory, but in the understory as well, and can both eliminate important food plants for rare animals and threaten rare plants. The understory in White Pine stands is also less dense and diverse than in Pitch Pine-Scrub Oak communities, threatening those rare or declining species that rely on understory vegetation for forage or cover.

IUCN Threat 6: Human Intrusions and Disturbance
Groundwater-contamination remediation activities often result in damage and fragmentation of important habitat. This is particularly problematic in PPSO communities, where disturbance of dry, nutrient-poor, sandy soils resulting from installation of remediation infrastructure such as roads and staging areas may take decades to revert to native vegetation. Such soil disturbance may also provide inroads for nonnative invasive plant species.

Operation of off-road vehicles (ORVs) is a common occurrence along utility line rights-of-way, unpaved roads, and trails, and is a problem on most public lands in Massachusetts. Even where ORV use is prohibited, enforcement is often idifficult, resulting in significant and damaging ORV intrusion. Utility rights-of-way, unpaved roads, and trails in PPSO systems often attract sensitive species for nesting (e.g., Eastern Box Turtle, Barrens Tiger Beetle), basking (e.g., North American Racer, Eastern Hog-nosed Snake), or foraging (e.g., Barrens Tiger Beetle). In these cases, ORV traffic may result in destruction of turtle nests and tiger beetle burrows, and in direct mortality of turtles, snakes, and beetles. In PPSO communities subjected to ORV traffic, the resulting disturbance of dry, nutrient-poor, sandy soils may take decades to revert to native vegetation. Such soil disturbance may also provide inroads for nonnative invasive plant species.

Where PPSO systems occur on public lands with trail systems, recreational uses pose threats to some species of conservation concern. Hikers occasionally collect Eastern Box Turtles that they encounter on trails (to keep as pets, or to “rescue” and release elsewhere). Snakes, particularly large or poisonous snakes, are occasionally killed by people out of fear, and domestic dogs may harass or kill snakes (NHESP database).

IUCN Threat 7: Natural System Modifications
The exclusion of fire from PPO forest, and fire-dependent PPSO habitats in particular, has contributed to habitat homogeneity, with open areas and shrub species giving way to mesic closed-canopy forests. This renders PPSO habitats unsuitable for a large number of SWAP animals and plants.

PPO habitat is a matrix of forest and non-forest types. Not only are grasslands and heathlands part of the system, but also Coastal Plain Ponds tend to be in the same areas as parts of the larger system. Water withdrawal from wells affects all of these habitat subtypes. For example, frost bottoms with wetlands at the bottoms that intersect the water table are affected by lowering of the water table by human ground-water withdrawals.

IUCN Threat 8: Invasive and Other Problematic Species, Genes and Diseases
Invasive species lead to alteration of upland forest ecosystems in Massachusetts, and threaten to cause increasingly dramatic alterations in the coming decades. Introduced fungi are responsible for chestnut blight, Dutch elm disease, beech bark disease, and butternut canker, while detrimental introduced insects include Gypsy Moth (*Lymantria dispar*), Winter Moth (*Operophtera brumata*), and Hemlock Wooly Adelgid (*Adelges tsugae*) (Gottschalk and Liebhold 2004). An emerging invasive fungal threat involves Ranorum blight (a.k.a. sudden oak death), which was first documented in California, and has the potential to devastate eastern oak forests if it becomes established here (Gottschalk and Liebhold 2004). Other invasive, exotic insects that could become established in Massachusetts forests include the Asian Long-horned Beetle (*Anoplophora glabripennis*), which attacks maple trees, and the Emerald Ash Borer beetle (*Agrilus planipennis*).

The introduction of generalist parasitoids as biocontrol agents has contributed to the decline of native Lepidoptera. The most notorious of these is a species of tachinid fly, *Compsilura concinnata*, which has been recorded killing over 180 different species of native Lepidoptera, Coleoptera, and Symphyta in North America (Boettner et al. 2000).

Some exotic plants are well-suited to invading the dry, nutrient-poor, sandy soils of PPSO habitats. Examples include Autumn Olive (*Elaeagnus umbellata*), and Two-colored Tick Trefoil (*Lespedeza bicolor*), which is capable of nitrogen fixation and can outcompete many native plants.

Overabundant deer excessively browse vegetation, including some plants of conservation concern. Overbrowsing by deer is also a threat to Lepidoptera and other animals that depend on particular plants for food, for example, the New Jersey Tea Inchworm, Frosted Elfin butterfly, and Persius Duskywing butterfly.

The extent of European earthworm invasion in Massachusetts has not been adequately quantified, nor have impacts on Massachusetts upland forests been directly studied. Numerous studies have shown the impacts that invasive terrestrial earthworms have on forest soils (e.g., Bohlen et al., 2004). A study in Minnesota Sugar-Maple-dominated northern hardwood forests similar to those of northwestern Massachusetts found earthworm invasion fronts were characterized by rapid reductions in the thickness of forest floor organic soil layers (Hale 2005). More recent studies (e.g., Hopfensperger et al. 2011) have consistently found that both plant cover and plant species diversity are lower in areas of northern hardwood forests with multiple earthworm species.

Although the decline of New England Cottontail corresponds with the introduction of Eastern Cottontail, interaction between the two species has not been well-studied, and it is unclear if competition is a factor.

IUCN Threat 9: Pollution
Massachusetts is nearly out of compliance with EPA standards for ozone and small particulates due to the atmospheric trajectories from metropolitan areas and from coal-burning power plants upwind of the state. The threat of noncompliance has lead to MassDEP restrictions on the permitted numbers and seasonality of prescribed fires.

Treatment of past pollution of groundwater on Cape Cod, particularly of the contaminated aquifer under the Massachusetts Military Reservation, has caused a great deal of disturbance to the current surface vegetation and affected the hydrology of the groundwater.

IUCN Threat 10: Geological Events
Geological events are not a threat to these systems.

IUCN Threat 11: Climate Change and Severe Weather
Due to inherent resiliency and dependence on disturbance, the Climate Change Vulnerability evaluation concluded that PPO forest PPSO habitats are at moderate risk, and may expand and migrate northward. Changes in the timing and magnitude of precipitation events could restrict the number of days available for prescribed burning each year. Changes in both precipitation and temperature patterns are likely to reduce suitability for tree species in the Northern Hardwoods-Spruce-Fir habitat region.

Climate change was addressed in *The Conservation Strategy for the New England Cottontail* (Fuller and Tur 2012) and determined not to be a threat to habitat for New England Cottontail.

The Twilight Moth is at the southern extent of its geographic range in Massachusetts; this species may retreat northward with climate warming, resulting in its extirpation from the state.

Conservation Actions for Upland Forests

Direct Management of Natural Resources
In Central Hardwoods-White Pine habitats, DFW will continue to employ even-aged forest-cutting practices that can successfully regenerate oaks. These efforts serve as a model for private forestland owners who have the goal of providing quality fish and wildlife habitat on their lands.

Because of the large number of state-listed/SWAP species inhabiting PPO communities on state land (and PPSO habitats in particular), these areas are a high priority for both additional land protection and increased restoration and management using both prescribed fire and mechanical treatment. In addition, DFW works under formal partnership with the USDA’s Natural Resource Conservation Service (NRCS) to plan habitat management projects on privately owned land aimed specifically at benefitting SWAP species. Projects are funded through the United States Department of Agriculture’s Farm Bill programs. Funding is offered for tree-canopy thinning, firebreak creation, and prescribed burning.

In 2012, the U.S. Fish & Wildlife Service and the NRCS established the Working Lands for Wildlife program, which provides funding specifically for managing habitat for New England Cottontail and six other federally listed or federal candidate species. These projects are being completed in conjunction with management on federal, state, and municipal land also taking place under *The Conservation Strategy for the New England Cottontail* (Fuller and Tur 2012). In addition, DFW is working with staff from the joint Base Cape Cod to manage PPSO habitat and monitor the New England Cottontail population.

DFW developed Best Management Practices (BMPs) for controlling the spread of invasive species (http://www.mass.gov/eea/docs/dfg/dfw/habitat/grants/bmp-invasives.pdf). This involves thoroughly cleaning the exterior, undercarriage, and tires/tracks of equipment being used for management with a high-pressure washer prior to arriving on a property, to reduce the risk of invasives being introduced from other locations. Following the BMPs is required for contractors working on DFW land and recommended for management projects on private land.

Data Collection and Analysis

While New England Cottontail has declined dramatically throughout its historical range, this species has persisted in greater numbers on Cape Cod than elsewhere in Massachusetts. Long-term monitoring of occupied sites such as those on the Cape is necessary to evaluate habitat use over time and the response of populations to various management approaches. Long-term monitoring is also needed to assess abundance and occupancy rates; this will require repeat visits to both managed and unmanaged sites. Because New England Cottontail and Eastern Cottontail are indistinguishable in the wild, the study of New England Cottontail involves intensive effort; DNA is extracted from tissue taken from trapped rabbits or fecal pellets collected during winter on fresh snow (to reduce DNA degradation). Competition between New England Cottontail and Eastern Cottontail is not well understood, and additional research to examine interactions between these species and their respective responses to habitat management is needed.

Moths, butterflies, and tiger beetles that depend on PPSO habitat are among the most frequently surveyed insects in Massachusetts. For example, a 2-year study currently underway will result in a significantly better understanding of the distribution and microhabitat needs of the Barrens Tiger Beetle and the Purple Tiger Beetle in PPSO habitat in Myles Standish State Forest. However, for insects, determining population trends and their causes is generally time- and cost-prohibitive. Therefore, most surveys for state-listed/SWAP insects consist of presence/absence data and habitat associations. Future monitoring of these species, to the extent possible, should investigate correlations with habitat management and/or natural disturbance events, and on average should occur every 10 years at any given site. The life history and habitat requirements of some state-listed/SWAP species that occur in PPSO habitat (for example, the Barrens Metarranthis) are completely unknown. In order to better inform habitat management and other conservation efforts, research to elucidate the natural history of such species is a priority.

Similarly, research on the natural history of rare orchids associated with PPSO habitat is a priority. For example, additional information on the natural history of Bayard's Adder's Mouth would be helpful in determining the management needs of these species—for example, are there important mycorrhizal associations that could be enhanced or encouraged?

Education and Outreach

Further education of both the public and other regulatory agencies about the value of PPO habitats and the issues related to their conservation is a priority. This may be accomplished through publications and other forms of public outreach. For example, the Wildlife Management Institute maintains a website dedicated specifically to New England Cottontail conservation. In partnership with the NRCS, DFW staff work to make direct contact with private landowners, and hold public presentations designed to encourage them to apply for Working Lands for Wildlife funding to manage PPSO habitat. DFW staff are also working with the Pine Barrens Alliance on publicity and guiding them on work they can do.

Harvest and Trade Management

Harvest of various furbearer species by licensed hunters and trappers occurs within upland forest habitat, in accordance with Massachusetts statutes and regulations.

Land and Water Rights Acquisition and Protection

Many conservation organizations and agencies, including the DFW, are actively involved in land conservation throughout Massachusetts. Both fee-simple acquisitions (where all the rights in land are transferred), and conservation easements (where development and other rights are transferred to the easement holder, but the underlying fee is still held by the original owner) are used to protect land. Conservation easements offer a cost-effective way to protect extensive forestlands that buffer rare habitats and communities because easements typically cost 20% to 40% less than fee-simple acquisitions.

DFW and other conservation groups consider protection of PPSO habitats with populations of state-listed/SWAP species to be a high priority. The Natural Heritage & Endangered Species Program (NHESP) recently produced *BioMap2* to help guide proactive land protection efforts statewide, including for Forest Core Habitats in all ecoregions statewide. *BioMap2* is used intensively by conservation groups at all levels to guide land protection.

In addition to *BioMap2*, DFW has also created a GIS data layer to identify forest interior habitat that is buffered from the fragmentation associated with roads and development. The forest-interior datalayer will help guide proactive land protection efforts for conserving extensive, relatively unfragmented forestlands that benefit a wide range of wildlife species. Viable populations of wide-ranging species such as Black Bear and Moose are best conserved within extensive, heavily forested landscapes. In addition, smaller wildlife species, including some forest songbirds, have higher likelihood of nesting success in large forest patches (Robbins 1989). In extensive, unfragmented forests, isolation (distance from the nearest forest edge) is the best predictor of population density and species richness for interior forest birds (Askins et al. 1987, Askins et al. 1991).

Sites that comprise both *BioMap2* Key Sites and forest-interior habitat should constitute some of the highest priority areas for land conservation in the state.

Law Enforcement
A lack of enforcement on lands where off-road vehicle (ORV) use is prohibited has resulted in considerable and ongoing damage, particularly to PPSO habitats due to their occurrence on sandy, easily-eroded soils. Expanded enforcement of ORV exclusion is greatly needed in these areas.

Legal mandates of the Massachusetts Endangered Species Act (MESA; M.G.L. c. 131A) and regulations (321 CMR 10.00) should continue to be implemented. The NHESP regulates environmental impacts to Upland Forest systems where they are known to function as habitat for species listed as Endangered, Threatened, or Special Concern pursuant to the MESA. Published delineations of Priority Habitat for those species define specific geographic areas where most types of proposed land, water, or vegetation alterations are required to be reviewed and approved in advance by the NHESP. The review process can involve adjustment of project plans to avoid or minimize impacts to forested habitats and their associated MESA-listed SGCN, or require mitigation of impacts that are deemed unavoidable. The MESA also provides for criminal and civil penalties for any unauthorized take of MESA-listed SGCN.

Other laws that protect SGCN associated with vernal pools within Upland Forest habitats should be enforced. Hunting regulations (321 CMR 3.05) prohibit disturbance, harassment, or other taking of certain SGCN associated with Upland Forest systems, such as Eastern Spadefoot, Eastern Box Turtle, and Eastern Hog-nosed Snake.

Law and Policy
Regulations and policies should be developed or updated as necessary to address emerging threats. The need to adopt new regulations and/or policies may arise as knowledge is gained about climate change, emerging infectious disease, animal trade, and other threats.

Planning
Develop detailed conservation and recovery plans for SGCN associated with upland forests in Massachusetts. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on upland forest SGCN populations.

Habitat management site plans for high-priority sites have been and will continue to be developed. These site plans usually include these sections: an overview; site context and significance; lists of rare species and natural communities documented on or near the site; existing conditions; site history; desired conditions, including goals, objectives, and descriptions of desired conditions; and management actions in detail, including initial restoration and long-term actions. Depending on the site, the site plan may be accompanied by more specific treatment plans for forest-cutting, prescribed fire, invasive-species control, grassland restoration, biological monitoring for target species and communities, and other management activities as needed.

Most of the habitat management activities underway in Massachusetts currently are aimed at restoring or maintaining grasslands, heathlands, or barrens habitats. Without similar management, the many thousands of acres of xeric oak habitats in the state will succeed to more mesic-influenced forest types because fire has been very thoroughly suppressed in these habitats. Therefore, planning and implementation for restoring and maintaining xeric oak forests should be developed and should prioritize efforts among potential sites.

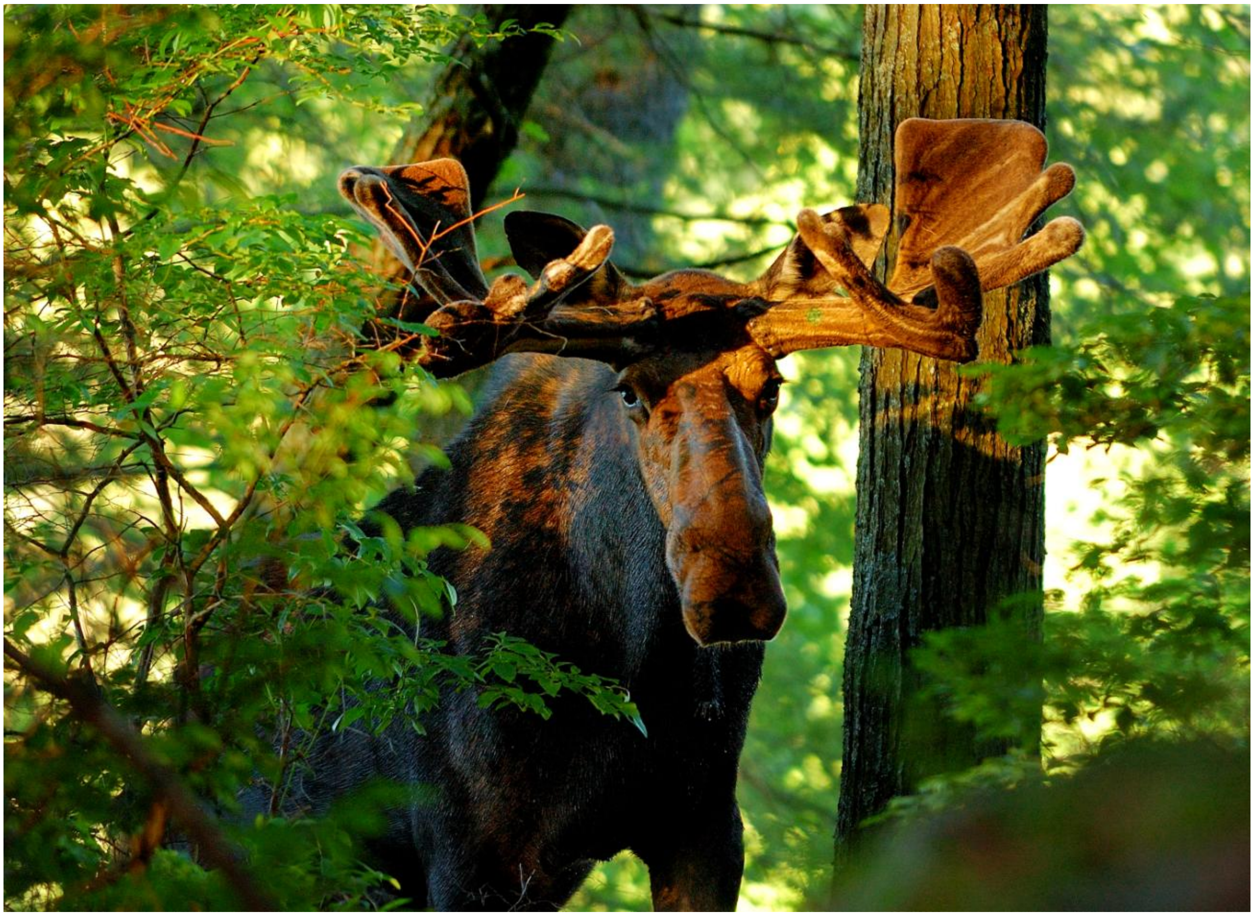
The DFW, along with the U.S. Fish & Wildlife Service, other state agencies, the Wildlife Management Institute, and the NRCS participated in development of *The Conservation Strategy for the New England Cottontail*. This conservation strategy was designed to utilize an adaptive approach to ameliorate threats to the New England Cottontail through the year 2030. Habitat loss and fragmentation was identified as the proximate threats to the New England Cottontail. The conservation strategy includes target goals for both habitat management and land protection.

Species Reintroduction and Stocking
The Conservation Strategy for the New England Cottontail (Fuller and Tur 2012) includes a captive breeding program. Since 2010, captive-breeding specialists at Roger Williams Park Zoo in Providence, Rhode Island, have been working to perfect housing, feeding, and breeding techniques so that New England Cottontails can be bred in captivity. Efforts are aimed at releasing captive-bred rabbits to the wild, both to boost the numbers and genetic diversity of existing populations and to start new populations on lands where New England Cottontail habitat is being managed. This effort recently expanded to include captive breeding at the Bronx Zoo in New York, using founder rabbits from Cape Cod, Massachusetts.

DFW is researching the potential for assisted migration of common tree species within the state on the basis of climate changes.

Links to Additional Information

- The Southeastern Massachusetts Pine Barrens Alliance
- The North Atlantic Fire Science Exchange
- Working Together for the New England Cottontail
- NRCS: A Bunny Tale - Working Together for the New England Cottontail on Cape Cod



Large Unfragmented Landscape Mosaics

Habitat Description

"Large unfragmented landscape mosaics" refers to the aggregation of habitat patches, corridors, and matrices of adequate size and connectivity to support the residency and long-term viability of wildlife populations, particularly those of wide-ranging species such as Bobcat, Black Bear, and Moose, which may serve as focal species for landscape-level habitat assessments. Similarly, but on a somewhat smaller overall scale, Blanding's and Spotted turtles move considerable distances (up to 2 km for Blanding's) among feeding, nesting, aestivating, and overwintering habitats, incurring increased vehicular mortality as a result. The relatively large home ranges and varied habitat requirements of these animals extend beyond habitat patches to landscape mosaics that are comprised of a mix of ecosystems on a scale of kilometers.

A more precise definition and measurement of the suitability of large landscape mosaics likely depends on the species; however, natural lands that include both forest and open wetlands may be considered as a general descriptor for this habitat type. Based on a landscape analysis, natural lands are primarily (90%) composed of forest, but also include open wetland habitats, and comprise about 63.5% of Massachusetts. Other habitat types may be included in a large unfragmented landscape mosaic depending on the type and size of those other habitat types and the species in question. For example, limited development, small-scale agriculture, or a natural grassland may provide food sources for a variety of species while serving as protective cover that connects forest blocks. One metric that can be used to conceptualize large unfragmented habitat mosaics are the Landscape Blocks developed in *BioMap2*. Landscape Blocks identify relatively intact landscapes that provided for ecosystem processes, habitat for wide-ranging species, and a mosaic of natural land cover types. Landscape Blocks account for 1,338,663 acres and represent the most intact 36% of the total area of natural land cover in Massachusetts (Figure 4-21). The largest landscape block encompasses the Quabbin Reservoir and the majority of large Landscape Blocks occur west of the Connecticut River, with the exception of three large Landscape Blocks in Southeastern Massachusetts: the areas including and around Myles Standish State Forest, Freetown State Forest, and the Massachusetts Military Reservation. Within the I-495 belt, the size of Landscape Blocks decreases dramatically and the area within the I-95 belt is largely devoid of any Landscape Blocks (Figure 4-22). For a detailed discussion on how landscape blocks were developed, see the *BioMap2* Technical Report - Components of Critical Natural Landscape (http://www.mass.gov/eea/docs/dfg/nhesp/land-protection-and-management/biomap2-tech-ch4.pdf).

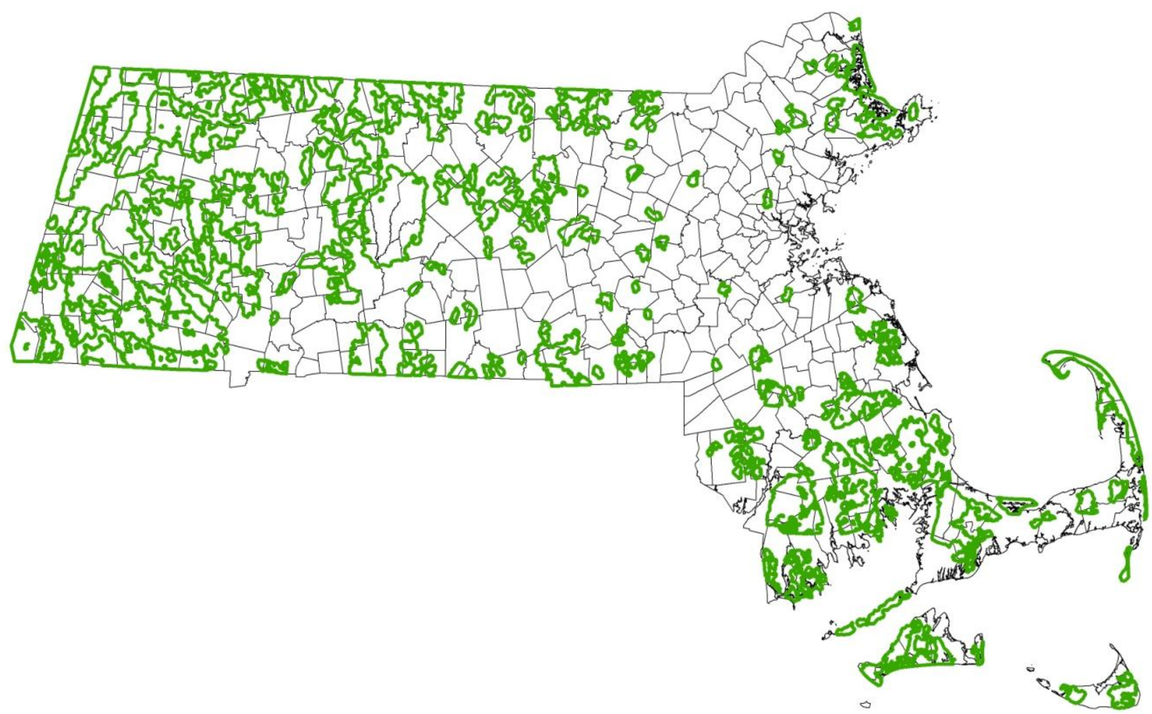


Figure 4-21: Landscape Blocks in Massachusetts.

These data are from the *BioMap2* Critical Natural Landscape datalayers.

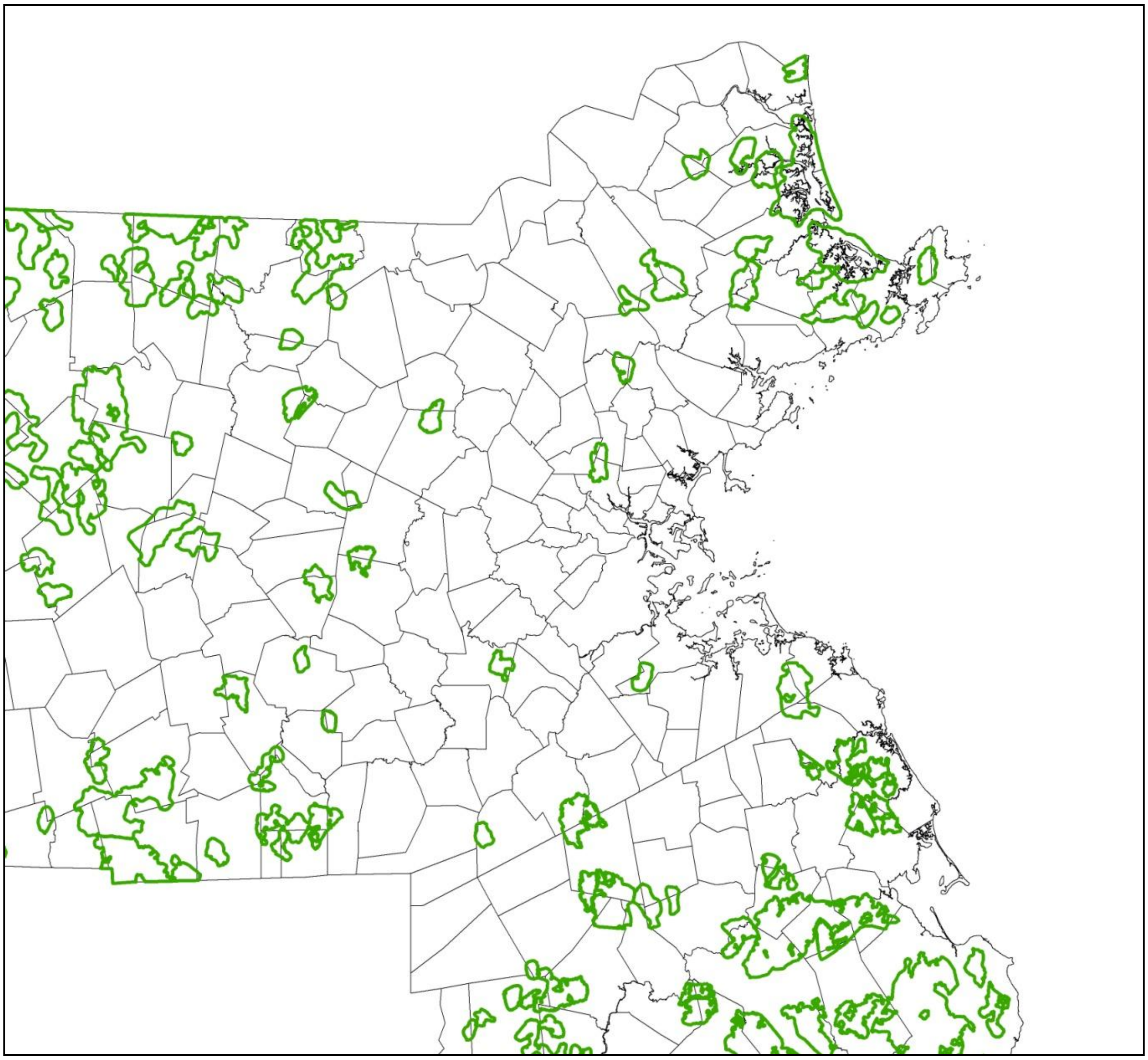


Figure 4-22: Landscape Blocks in eastern Massachusetts.

These data are from the *BioMap2* Critical Natural Landscape datalayers.

Species of Greatest Conservation Need in Large Unfragmented Landscape Mosaics

Five SGCN are assigned to the Large Unfragmented Landscape Mosaics habitat (Table 4-16).

Reptiles

Spotted and Blanding's turtles are long-lived reptiles, with delayed reproductive maturity (about 8 years for Spotted, 17.5 years for Blanding's), low annual reproductive output (2-7 eggs/year for Spotted, 3-22 eggs/year for Blanding's), and high mortality rates in the egg and hatchling stages. These life-history characteristics imply that adult turtles must have a very high annual survivorship rate (estimated at 93% or greater) to offset low recruitment to adult ages and, thus, maintain stable populations (Congdon et al. 1993; Fowle 2001).

Additionally, a population of Blanding's or Spotted turtles uses a variety of wetland and upland habitats in a single year. Individual turtles can also move long distances between habitat types in a single year.

Blanding's Turtles in New England use ponds, rivers, marshes, fens, vernal pools, shrub swamps, forested swamps, streams, meadows, forests, and shrublands for foraging, aestivating, overwintering, basking, hydrating, and movement between wetlands. Nesting sites include meadows, fields, pastures, bedrock outcrops, sand and gravel pits, dirt roads, and roadsides (Fowle 2001; Joyal et al. 2001). Joyal et al. (2001) found Blanding's Turtles in southwestern Maine to spend greater than 50% of their time from May to September in permanent pools, and 38% of their time in uplands of various types. In Massachusetts, Milam and Melvin (2001) documented that Spotted Turtles spent about two-thirds of their active season in seasonal pools. Fowle (2001), summarizing several studies of radio-tracked Blanding's Turtles, noted the maximum average of 680 meters in one study, with a maximum of 2900 meters in another, traveled between wetlands. The maximal average distance traveled to nesting sites was 895 meters, with a maximum single distance of 1620 meters. Congdon et al. (2011) determined that terrestrial protection zones of 1,000 and 2,000 meters around residence wetlands at a site in Michigan were necessary to protect 87% and 100% of adult Blanding's Turtles, respectively.

Spotted Turtles in New England use ponds, emergent marshes, shrub swamps, forested wetlands, fens, wet meadows, seasonal pools, streams, rivers, forests, and other upland habitats. Nesting sites include open, non-forested uplands such as meadows, fields, pastures, sand and gravel pits, and roadsides, as well as hummocks in emergent wetlands and red-maple swamps (Fowle 2001; Joyal et al. 2001). In the same landscape as the Blanding's Turtles reported above, Joyal et al. (2001) found Spotted Turtles to spend about a third of their time in permanent pools. In 1992, Spotted Turtles spent more time in seasonal pools than in other habitats (permanent pools, uplands, forested swamps, and wet meadows), but in 1993, a drier year, they spent the largest percentage of their time in uplands. Overall, Spotted Turtles in this study spent about 74% of May through September in uplands. Fowle (2001) summarized movements of radio-tracked Spotted Turtles to nest sites and reported an average of 249 meters and a maximum of 570 meters. Maximum distance traveled between wetlands was 1150 meters.

Thus, these turtles use surprisingly large areas of landscape mosaics to carry out yearly activities. Coupled with the requirement for very high adult survivorship and the susceptibility to vehicular mortality while moving, protecting populations of Blanding's and Spotted turtles will require large landscapes composed of various wetlands and uplands in close proximity, unfragmented by roads and other development. Since, in Massachusetts, Blanding's and Spotted turtles occur primarily east of the Connecticut River, the more heavily developed and fragmented part of the state, conserving these species over the longterm will prove particularly difficult.

Mammals

The sensitivity of wildlife to decreasing patch size has been shown in California for mammalian carnivores such as Mountain Lions (*Puma concolor*), Bobcats, and Coyotes (*Canis latrans*), where the probability of occurrence of individuals of those species decreases as habitat patches became smaller and more isolated. However, sensitivity to these landscape variables depends on the species (Crooks 2002). Bobcats were found to have significantly greater sensitivity to size and isolation than Coyotes and mesopredators such as Raccoons (*Procyon lotor*), skunks (*Mephitis* spp. and *Spilogale* spp.), and Opossums (*Didelphis virginiana*).

Wide-ranging species such as Bobcat, Black Bear, and Moose may also be especially sensitive to road density (Paquet and Hackman 1995; Hammond 2002; Lovallo and Anderson 1996; Reed 2013; Wattles and DeStefano 2013). The following characteristics have been identified that increase a species' vulnerability to road effects such as road mortality, habitat loss, and reduced connectivity between habitats (Forman and Sperling 2003):

- Attraction to road habitat
- High intrinsic mobility
- Habitat generalist
- Multiple-resource needs
- Low density / large area requirement
- Low reproductive rate
- Forest interior species
- Behavioral avoidance of roads

Depending on sex, seasonality, and region, home ranges for Bobcat, Black Bear, and Moose will vary substantially, but in general are very large and encompass multiple habitat types. Reported home ranges for adult Bobcats may vary from 2 to 123 km^2 for males and 1 to 70 km^2 for females (Anderson and Lovallo 2003). Mean home ranges for male and female Bobcats in New Hampshire were 93.5 km^2 and 29.7 km^2, respectively (Broman 2012). Adult female (more than 2 years old) Black Bear home ranges in two western Massachusetts study areas averaged 23 and 26 km^2 (Fuller 1993) and adult males 328 km^2 (Elowe 1984). Preliminary average home range estimates of Massachusetts adult female Black Bears from 2009–2014 show large differences in home range size for bears west and east of the Connecticut River, 45.08 km^2 and 211.78 km^2, respectively (DFW unpublished data). Studies in northern New England have shown mean summer home-range sizes for Moose of 2 to 60 km^2 to as much as 93 km^2 and 153 km^2 (DeGraaf and Yamasaki 2001). Wattles and DeStefano (2013) reported mean annual home range sizes of male and female Moose in Massachusetts to be 88.8 km^2 and 62.2 km^2, respectively. Within their home range, Moose require a variety of cover types to meet their annual energy demands and the connectivity between these cover types is important (Wattles and DeStefano 2013). Wattles and DeStefano (2013) found that Moose selected for areas of regenerating forest during most of the year, which was relatively interspersed and fragmented on the landscape in Massachusetts (Wattles and DeStefano 2013).

While the home ranges and particular habitat features required by these focal species have been studied (DeGraaf and Yamasaki 2001), their sensitivity to fragmentation of the landscape and landscape mosaic area size is not well known in Massachusetts. There is increasing evidence that variables such as habitat patch size, distribution, and connectivity significantly affect biodiversity and wildlife populations at the landscape scale (Manville 1983; Mattson 1990; Forman 1995). In eastern Massachusetts, road effects (avoidance) extended outward more than 1 km for Moose corridors (Forman and Deblinger 2000). Human development may limit the range of Moose in Massachusetts as Moose home ranges were primarily made up of forested habitat and had lower road densities compared to the surrounding habitat (Wattles and DeStefano 2013). Roads may be of particular importance when they compromise large unfragmented habitat mosaics. Wattles (2014) determined that roads had a negative effect on Moose movements and habitat selection and road avoidance increased with higher traffic volumes and busy times of day.

The preeminent management challenge for Black Bear in Massachusetts is to maintain a viable population over as broad an area as practical, while simultaneously preventing or mitigating the bear-human conflicts which arise from the increasing fragmentation of forested habitats and the consequent interspersion of people and bears. Although, in Massachusetts, Black Bears are resilient to much environmental variation and are good at adapting to human-dominated landscapes (McDonald 1998), there are many challenges facing Black Bear management. These threats may involve both intrinsic biological traits and exposure to external human-associated activities (Cardillo et al. 2004). Human alterations to Black Bear habitat may degrade or alter the food biomass available to bears and coincidentally induce changes in the bears' tolerance to humans, and that of humans to bears. The ability to sustain Black Bears in Massachusetts and to retain public support for a Black Bear population will be challenging due to habitat loss, fragmentation, proliferation of human-associated food sources, as well as other landscape-level changes.

Hammond (2002) found that in Vermont adult male Black Bears avoided areas within 200 m of permanent houses and adult females within 200 to 400 m, depending on season. Adult males avoided paved roads out to 400 m and adult females out to 300 m (Hammond 2002). However, in Massachusetts, Black Bear conflicts are increasing as the population grows and moves east into the more populated areas of the state. From 2010-2014, Black Bears accounted for the highest number of phone calls to DFW (DFW unpublished data). Black Bears may be most attracted to human-dominated landscapes because of the attraction of easy, high-calorie food sources such as birdseed. One GPS-collared adult female in the city of Northampton visited a known feeding site 18 days out of the month of May 2011, crossing Interstate 91 on several occasions to visit the site (DFW unpublished data). As large habitat mosaics become increasingly fragmented, Black Bears will likely increase their use of the human-dominated, landscape leading to increased human-bear conflicts.

Lovallo and Anderson (1996) found that in Wisconsin, areas ≤100 m from roads contained less preferred Bobcat habitat than roadless areas. Geographic and behavioral selection appeared to be a function of vehicular traffic levels and the proximity of preferred habitat to road types. Reed (2013) found that Bobcats in New Hampshire appeared to be limited by human development, mainly roads at a fine scale, as they selected against developed areas and avoided areas of high road density. Bobcats showed the highest selection for wetlands and scrub/shrub forest habitats (Broman 2012, Reed 2013). Bobcats have been reported and documented near human development and may be attracted to human-related food sources or small mammal populations that often thrive in the backyard setting. The more development becomes interspersed throughout the landscape, the greater the potential for human-Bobcat conflicts and vehicle-related Bobcat mortality.

Table 4-16: Species of Greatest Conservation Need in Large Unfragmented Landscape Mosaics

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Emydoidea blandingii*	Blanding's Turtle
	Clemmys guttata	Spotted Turtle
Mammals	*Alces alces*	Moose
	Lynx rufus	Bobcat
	Ursus americanus	Black Bear

Threats to Large Unfragmented Landscape Mosaics

IUCN Threat 1: Residential and Commercial Development

Fragmentation and habitat loss are frequently identified as primary threats throughout this document and directly relate to the definition of large unfragmented landscape mosaics. The two major causes for habitat loss and fragmentation are human development and road networks, which break up habitats into smaller pieces and isolate those habitats by creating barriers and resistance to animal movement. Development, associated habitat loss, fragmentation, and traffic are believed to be the greatest threats facing Blanding's and Spotted turtles in Massachusetts today. Blanding's Turtles are particularly imperiled due to their long movement distances, small population sizes, and spotty distribution, concentrated in the eastern part of the state where development pressure is greatest. Road mortality can be significant and can lead to male-skewed sex ratios and other changes in mating system structure, movement ecology, and genetic diversity (Anthonysamy et al. 2014; Reid and Peery 2014; Proulx et al. 2014). Residential development may lead to increased Blanding's Turtle mortality both through direct effects (road mortality) and indirect effects on predator populations (Jones and Sievert 2012). Fowle (2001), in her summary of threats to Blanding's and Spotted turtles (among other reptiles and amphibians), notes that roads, railroad tracks, fences, retaining walls, and curbs can all serve as barriers to turtle movements, thus isolating populations and increasing their chances of local extinction. Direct wetland loss is also identified as a threat, as well as activities that degrade the habitat value of the wetlands or their immediate vicinity, such as loss or thinning of forest canopy or removal of rocks or coarse woody debris (which shelter prey such as amphibians). Turtles can also be threatened by the edge effects of human residential use, such as an increase in mesopredators (raccoons, skunks), the taking of turtles as pets, injuries or mortality caused by pets, and disturbance of nesting activity by humans or their pets.

Residential and commercial development and the road networks that often accompany these can be detrimental to Moose, Black Bear, and Bobcat, due to the increased chance of vehicle collisions. Further, development removes important habitat, reduces forest continuity, and can lead to increased travel requirements. Black Bear may prefer to use alternative food sources that are found within residential areas, which can increase the chance of human-bear conflicts. Bears may become more vulnerable to vehicle collisions, and bears may lose their fear of people, leading to individuals being euthanized as public-safety threats. Direct habitat loss through human development is an obvious threat, but the consequence of human development poses a more indirect subtle threat by artificially increasing, modifying, or degrading the food biomass available to these species. In part, increased availability of food combined with road/infrastructure networks attracts wide-ranging mammalian species into human-dominated landscapes. While these species may occur in suburban or urban landscapes, such landscapes may not necessarily ensure the long-term residency or persistence of these species. At present, populations of Black Bear are increasing in Massachusetts, despite the fact that some 10,000 acres of forest are annually converted to suburban development. While these population increases within a landscape that is continually being developed may be seen as indicating that bears can easily coexist with dense human settlements, they may also be the result of semi-urbanized landscape conditions that are still within the tolerance of these species. Further, the tolerance of humans to the presence of these species within more urbanized communities may pose special conservation challenges in the future. Clearly, at some point along the continuum of fragmentation and development, the availability of large enough landscape mosaics to support certain species will diminish.

IUCN Threat 2: Agriculture and Aquaculture

As both Spotted Turtles and Blanding's Turtles frequently nest at anthropogenic features such as agricultural fields and cranberry bogs (Beaudry et al. 2010), agricultural activity poses a potential threat of adult mortality and nest loss. At the same time, agriculture and other human activity may create important nesting habitat, so the effects of agriculture on these species are complex. Agricultural habitat, when interspersed with forest, often provides food sources for Black Bear, and may provide food sources for Bobcats in the form of small mammals. Black Bear can cause significant damage to corn, orchards, and other agricultural crops, which can lead to conflicts and significant monetary losses for farmers. Large-scale conversions of forest to agriculture, as occurred in the mid-18th century, would be detrimental to Moose, Black Bear, and Bobcat because it removes critical habitat.

IUCN Threat 3: Energy Production and Mining
Although resource extraction is not a major threat to large landscape mosaics in Massachusetts at this time, there is the potential for fragmentation to occur, even at small scales.

IUCN Threat 4: Transportation and Service Corridors
Roads and rail lines have the potential to serve as a barrier to turtle movement and may be significant movement barriers. Rail lines may act as travel corridors for wide-ranging species, such as Moose, Black Bear, and Bobcat, since these areas often go through forest patches and train frequency can be low. However, even with low train frequency, the potential for Moose or bear-train collisions can pose a public safety threat. Wildlife-vehicle collisions, especially with Moose or bear, can pose a significant threat to public safety. Movements among a variety of habitat types coupled with large movement distances make Blanding's and Spotted turtles particularly vulnerable to vehicle-induced mortality. More research is needed into the effects of roads and rail lines on the movement ecology of a variety of species including state-listed turtles and salamanders. Moose may be particularly vulnerable to increased road infrastructure. Massachusetts leads the Northeast with the proportion of the estimated Moose population struck by vehicles per year (2013 Northeast Moose Technical Committee Meeting). Wattles (2014) found that Moose were more likely to cross smaller, low-traffic roads, but the majority of Moose-vehicle collisions occurred on interstates and highways, and were more likely to occur when the roadway bisected relatively intact ecological features.

There are numerous service corridors, in the form of transmission lines and pipelines, in Massachusetts and there is the potential for more to be constructed as the human population increases. While transmission lines fragment large landscape blocks and can facilitate the spread of invasive species, they can also create habitat diversity that can increase species richness at the landscape scale, and provide habitat for a number of SWAP species, including state-listed turtles, Bobcat, bear and Moose. More research is needed into the effects of transmission corridors on a variety of SWAP species, and on how the effects are influenced by specific vegetation management regimes. Powerline and pipeline corridors can be beneficial wildlife travel corridors, and can provide food and cover, especially when the habitat is managed to be thick young forest or brushland, even if it is cut back every 5-10 years. However, when powerlines and pipelines consist of mowed grass or non-habitat, or restrict movement with materials above ground, they may cause fragmentation of large tracts of natural land cover types, and may provide opportunities for off-road vehicle use, which would likely be detrimental to the species discussed in this chapter.

IUCN Threat 5: Biological Resource Use
Collection of Blanding's and, in particular, Spotted Turtles is a potential threat, and the risk of ad hoc collecting facilitated by chance encounters with turtles likely increases as habitat fragmentation and human population density increase. The severity of this threat in Massachusetts is not well understood. Hunting of Moose is prohibited; however, as habitat fragmentation increases, Moose may become more vulnerable to increased poaching due to increased encounters with humans. Hunting is allowed for both Black Bear and Bobcat. Increased habitat fragmentation may make these species more vulnerable to harvest; however, the expected level of take would not be detrimental to their populations.

Timber harvesting (logging, pulpwood, etc.) that creates regenerating forest, can be beneficial to Black Bear, Bobcat, and Moose, due to increased food and cover.

IUCN Threat 6: Human Intrusions and Disturbance
Much of this threat is addressed and related directly to IUCN Threat 1. As large unfragmented landscape mosaics become fragmented by either development or roads, and as the human population increases, recreational activities such as hiking and off-road vehicle use may become more prevalent. Habitat disturbances of these types may result in increased incidental take of both Blanding's and Spotted turtles. Recreational activities such as hiking or camping that may generate food refuse could serve as an attractant to Black Bears, increasing the risk of human-bear interactions.

IUCN Threat 7: Natural System Modifications
Wetland loss and hydrologic alterations pose potential threats to Blanding's and Spotted turtles. Although Blanding's Turtles occupy a variety of wetland types, core wetlands in Massachusetts often include beaver-influenced shrub swamps and deep marshes. Historically, Blanding's Turtles most likely moved across the landscape in response to hydrologic changes associated with beaver activity. As landscapes are increasingly fragmented, beaver control and beaver dam removal pose a potential threat to Blanding's Turtles, as these activities may mean less suitable habitat is available and road mortality risk is greater for turtles, as they move across the landscape. Human alteration of the habitat that suppresses natural events, such as fire, flooding, etc., can often result in large tracts of older age classes of forest that offer less diverse and less abundant food resources for Moose, Black Bear, and Bobcat.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Please refer to other chapters (all types of upland forests, Shrub Swamps, Forested Swamps, and Young Forest and Shrublands) for a detailed discussion on the threats related to invasive species.

IUCN Threat 9: Pollution
Please refer to other chapters (all types of upland forests, Shrub Swamps, Forested Swamps, and Young Forest and Shrublands) for a detailed discussion on the threats related to pollution.

IUCN Threat 10: Geological Events
Large unfragmented habitat mosaics are generally not affected by geological events in Massachusetts. The greatest threat to this habitat type occurs on a relatively short time scale (less than a century) and is directly related to land conversion and threats associated with development.

IUCN Threat 11: Climate Change and Severe Weather
The effects of climate change will likely not result in increased threats for Blanding's or Spotted turtles. However, the predicted increases in precipitation and average temperature will affect small wetlands in complex ways, resulting in potential and complex effects on these turtles.

The range of Black Bear and Bobcat will likely not be affected by climate change; however, changes to the growing season of summer berry crops and fall hard mast, and the potential for an increase in short-term droughts could negatively impact bear and Bobcat food sources. Human-bear conflicts have been negatively correlated with the abundance of summer food sources, and if short-term droughts result in decreased summer berry crops and fall hard-mast failures, human-bear conflicts would likely increase (Northeast Black Bear Technical Committee 2012).

In general, climate change is detrimental to Moose in Massachusetts. Moose are at their southern historical range in Massachusetts, so an increase in climate temperatures would lead to increased heat-stress on Moose in the spring, summer, and fall, and more importantly, an increase in disease and parasites that can have a detrimental effect on moose populations (Rodenhouse et al. 2008). Moose have shown a remarkable adaptive capacity to physically deal with heat-stress by shifting movement and habitat selection patterns (Wattles and DeStefano 2014), but the physical impacts of thermal stress on Moose remain unstudied. Winter Tick (*Dermacentor albipictus*) appears to be a major concern for Moose currently, and climate change will likely exacerbate the issue by limiting the natural weather conditions that kill and limit tick numbers (snowfall and cold temperatures in the fall and spring; Rodenhouse et al. 2008). Meningeal Parasite (*Parelaphostronggylus tenuis*) is also presently a major concern for Moose in the southern part of their range, specifically where their range overlaps White-tailed Deer (*Odocoileus virginianus*), which carry the parasite. Thus, climate change that leads to range expansion and growth of the deer population (e.g., decreased snowfall and warmer temperatures) may increase the risk of the meningeal parasite on Moose (Rodenhouse et al. 2008).

Long-term droughts may be stressful to Black Bear, Bobcat, and Moose, because many of the food sources for these wildlife rely on are negatively impacted by drought. Severe weather events including microbursts, tornadoes, high wind events, and ice storms can lead to forest canopy openings, allowing for new growth that can provide beneficial food and cover to Black Bear, Bobcat, and Moose.

Conservation Actions

Direct Management of Natural Resources
Protect areas of high-elevation conifer cover that Moose rely on as refuges from heat and deep snow, which are crucial for sustaining Moose populations in Massachusetts (Wattles and DeStefano 2014). Create patch cuts (small clearcuts) in the forest, which can increase areas of young forest that can create crucial food and cover for a variety of species, including Moose, Black Bear, and Bobcat. A forest with a matrix of patches of conifer cover and regenerating forest can help alleviate travel demands on Moose in times of thermal stress and, even more importantly, decrease the risk of parasite and disease transmission by limiting unnaturally high concentrations of Moose around single food sources of regenerating forest.

Continue to work with the Massachusetts Department of Transportation (MassDOT) on the Linking Landscapes for Massachusetts Wildlife project to identify important wildlife crossings. Linking Landscapes works with volunteers and conservation professionals to identify hotspots of turtle and wildlife mortality and to remediate threats and improve landscape connectivity through the installation of crossing structures and barriers. Work with MassDOT and other organizations to create wildlife-crossing structures over or under major thoroughfares. The Division worked with MassDOT to develop a novel turtle-crossing structure between modified railroad ties that could have important applications elsewhere (Pelletier et al. 2005). Explore and implement other options to reduce vehicle-related wildlife mortality, including construction of wider stream culverts where land is available, use of wildlife fencing along appropriate roadways, and development of road signage to inform the public of potential wildlife crossings. Work with MassDOT and other organizations to monitor wildlife crossings and determine the effectiveness of various crossing structures and aids at reducing vehicle-related wildlife mortality.

Work with utility companies to refine vegetation-management and line-maintenance procedures to protect and enhance habitat for a variety of SWAP species, including state-listed turtles and plants. Enhance, create, and maintain nesting and early-successional habitat for listed turtles including Blanding's, Wood, Box, and Spotted turtles. Conduct targeted invasive-species management at priority sites.

Data Collection and Analysis
Examine the sensitivity of focal-species populations to fragmentation from roads, development, and changing land-use patterns. Utilize the results of recent studies on Moose, which incorporated the use of road-kill data, GPS data gathered from collared animals, and a detailed habitat analysis, to help identify ways to reduce Moose-vehicle collisions (Wattles and DeStefano 2013; Wattles 2014). Continue the cooperative Black Bear research project between the Division, the USGS Massachusetts Cooperative Fish and Wildlife Research Unit, and the University of Massachusetts. This study will utilize GPS collars to better understand Black Bear habitat use of the increasingly fragmented Massachusetts landscape and will identify statewide high-quality Black Bear habitat. Identify road mortality hotspots for target species through the Linking Landscapes project, and work with MassDOT to remediate them, when practical. Continue to support research into wildlife-crossing design. Determine the minimum land area and habitat features needed to protect meta-populations of landscape-mosaic species, for use in conservation planning. Continue to implement standardized long-term monitoring of turtle populations to detect regional and statewide trends. Continue the long-term monitoring of Black Bear population demographics to detect regional and statewide trends.

Education and Outreach
Educate the public about the value of large landscape mosaics or natural areas in supporting focal-species populations and biodiversity within Massachusetts. Educate the public on the value food and cover in large landscape mosaics has for a variety of species, and how the use of natural food/cover, over food/cover found in human developments, can reduce human-wildlife conflicts. Educate the public on the detrimental effects of increased development and fragmentation of large landscape mosaics. Continue to educate the public on the Linking Landscapes project to encourage reporting of road-related mortality for turtles and other wildlife species. Work with MassDOT to develop types and placement of signage to identify Moose road crossings to increase public safety and reduce Moose-vehicle collisions, especially at times of the year when Moose movements are high.

Harvest and Trade Management
Continue to monitor the harvest of Black Bear and Bobcat. Continue to make harvest management recommendations based on the best available science.

Land and Water Rights Acquisition and Protection
Identify and prioritize large landscape mosaics that are critical to the conservation of focal species and biodiversity within the state. Cultivate government and private partnerships focused on large-scale natural area protection. These efforts should be focused in northeastern Massachusetts for Blanding's Turtles and east of the Quabbin Reservoir for Spotted Turtles. Efforts should also be focused on critical habitat linkages for wide-ranging mammal species such as Black Bear, Bobcat, and Moose.

Law Enforcement
Regulate and limit the impacts of development on large unfragmented landscape mosaics used by state-listed animals. Monitor construction or alteration projects regulated by the Commonwealth under the MESA, for the impacts on landscape mosaic species.

Law and Policy
Continue to implement the MESA, including specialized programs to work with forestry operators, utility companies, and MassDOT.

Planning
Develop detailed conservation and recovery plans for SGCN associated with large unfragmented landscape mosaics. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Prioritize large unfragmented landscape mosaics across the state as targets for survey and conservation efforts. Synthesize research and survey findings, with subsequent production of conservation guidelines. Develop mitigation guidelines for road construction to minimize isolation and mortality effects on wildlife. Develop guidelines for community developments that minimize fragmentation of large landscape mosaics.

Continue the joint scenario-planning pilot project on Moose and boreal forests in light of climate change; see Chapter 5, Section D for details.

Species Reintroduction and Stocking
Consider the expanded use of headstarting to decrease local extinction risk for isolated Blanding's Turtle populations (http://www.grassrootswildlife.org/projects.php).

Small Streams

Habitat Description

Small streams are the first locations in the upper reaches of the watershed where rainfall, runoff, and groundwater come together to form a defined stream channel, typically with year-round flow. Small streams account for the majority of the linear stream miles in Massachusetts and connect catchments to sub-watersheds and mainstem rivers. They accumulate and assimilate all upstream inputs, perturbations, and degradations and transmit them to reaches downstream. They are the capillaries of the aquatic circulatory system. It has long been realized that healthy small streams contribute to the integrity of the watershed by maintaining the soil, increasing infiltration, reducing the impacts of flooding, and maintaining summer base flow. Small streams are where the River Continuum Theory begins. River Continuum Theory works on several concepts to describe the metamorphosis of a narrow canopy-covered channel, often with fast flow, to a wider, deeper channel with slower flows, which is naturally exposed to sunlight over most of its width. Consequently, the boundaries between small, medium, and large streams are gradients, not absolutes.

Examples of small streams would be first- to third-order streams with a full canopy of mature trees and associated understory. The channel would most often be less than 30 feet wide and the drainage area could be less than 30 square miles. These streams often have naturally low fish diversity, low productivity and relatively high gradients. The substrates may be dominated by boulder and cobble in high-gradient watersheds like the Westfield, or gravel and sand in lower-gradient watersheds like the Taunton. In most cases, small streams are dependent on groundwater for a high percentage of their annual flow and have food webs that are highly dependent on additions of nutrients from the surrounding vegetation.

Healthy small streams across the state would be expected to have varied fish communities. Coldwater streams can often support only a single species, often Brook Trout, or a few species in addition to Brook Trout, including Slimy Sculpin, Blacknose Dace, Longnose Dace, and others. In flowing waters that have water-quality problems, Blacknose Dace will often dominate as they are more tolerant of water quality degradation than other species. Other small streams can be dominated by fish tolerant of warmer waters, like Creek Chub or Fallfish. In almost all cases, healthy small streams would consist entirely of native fluvial (river) fish species.

Small streams experience a wide array of environmental conditions throughout the year. Summer flows are typically the lowest annual flows and can, at times, be near zero. Aquatic organisms that can find refuge during these extreme climate conditions can survive to repopulate. Spring flows are extreme in fluctuation and magnitude (excluding single events such as hurricanes, which are not annual). These habitats depend on high flows to redistribute sediments and provide water to floodplain ecosystems. Many species key in on these high flows to initiate the reproductive cycle. Fall and winter flows are typically moderate compared to spring and summer, but the environmental conditions can still be extreme due to harsh New England weather. Very cold winters can cause the formation of anchor ice that can freeze stream channels solid. Fish will find small refugia in which to survive or move downstream to medium and large streams that will likely have more refugia. Small streams are relatively unstable (stochastic) environments with associated flora and fauna that have come to adapt and, in some cases, rely on the harsh environment. It is the frequency and duration of these extreme events that will change as small streams are impacted by the threats listed below and it is the conservation actions also outlined below that will protect these resources.

No map of small streams is included here, simply because there are so many small streams in Massachusetts that at the scale of a map for this report, virtually the entire state would be shown as covered by a small stream. However, for the purposes of the SWAP, we consider small streams to be those coded as ARC_CODE 4 and 5 in the MassGIS hydrology datalayer, HYDRO25K_ARC, with the exception of any stream or river considered elsewhere in this report to be a Large and Mid-sized River.

Species of Greatest Conservation Need in Small Streams

Twenty-nine SGCN are assigned to the Small Streams habitat (Table 4-17).

Three of the state-listed fish of small streams are found only in localized portions of the state. American Brook Lamprey inhabit a few streams and small rivers in the southeastern part of Massachusetts, including on Martha’s Vineyard. Lake Chub have been collected only from the main branches of the Westfield River, in western Massachusetts. Northern Redbelly Dace are currently known only from one small tributary to the Green River in Franklin County.

Slimy Sculpins are creatures of small, cold, free-flowing streams in Massachusetts. They are most abundant in the high-gradient streams of the Berkshires and require high water quality as well as cold temperatures. They commonly associate with fast water and large substrates, like cobbles and boulders, and are often found even in cascading habitats. Although they represent a proportion of the fish in streams as large as the South River in Conway or the Sawmill River in Leverett, they thrive in even smaller streams. It is very conceivable that restoration efforts on mid- to large-size coldwater streams would enable Slimy Sculpin to recolonize those larger habitats.

The American Eel is a catadromous species, which spends most of its life in rivers, lakes and estuaries, but migrates to the ocean to spawn. Eels are capable of migrating several hundred kilometers from the ocean, taking up residence in small streams. These eels will remain there for the majority of their lives, for at least 5 and possibly as many as 20 years before returning to the sea to spawn and die.

Blacknose Dace and Longnose Dace are fluvial-specialist species that require free-flowing water year-round to survive. Their habitat preferences are somewhat different in that Blacknose Dace like small pools or runs within the riffle/pool-run matrix, and Longnose Dace will often be found in the faster water. Although not coldwater species, these fish are tolerant of a wide range of temperatures and are often associated with trout populations. Both species are often found within the same sampling effort. Blacknose Dace are a species relatively tolerant to water-quality degradations; Longnose Dace are considered moderately tolerant. Monitoring the change in Blacknose Dace relative abundance from mere presence to dominance over coldwater species can help determine when water quality has declined. Further declines in water quantity, quality, or physical habitat cause even these tolerant species to be replaced by generalist species. Where flows are maintained but water quality declines, Blacknose Dace tend to dominate the fish community. Better water quality is indicated by a mix of these, and other, species. The free-flowing habitats needed by these species have been highly degraded by impoundments, other physical habitat changes, and water quantity reduction.

Longnose Dace are similar in habitat use to Blacknose Dace but are more often associated with higher current velocities and have a lower tolerance for water quality degradation. Longnose Dace are also a fluvial specialist, as they require flowing water to meet all of their life history requirements. The high level of degradation to habitats used by Longnose Dace is the reason they are on the list of SGCN. The potential to restore habitat for Longnose (and Blacknose Dace) is also quite high.

Brook Trout are a coldwater species associated with small streams. The specific habitat needs within these streams are highly varied. Substrates from ledge to silt are all used to some extent by Brook Trout. They, like all fluvial specialists, require flows that mimic the natural hydrograph to meet their seasonal habitat needs. Brook Trout are also susceptible to degradations in water quality and have been impacted in many streams statewide. Physical habitat alteration and changes to water quality and quantity continue to reduce and restrict the amount of habitat available to Brook Trout in Massachusetts. Some streams no longer support the coldwater fishery resources they once supported; other streams have lost fish abundances that once made them extraordinary fisheries. Brook Trout are not only an indicator species of cold, clean water, but also a marquee species that can focus efforts and garner support from a wide segment of the public. Although the public often has a limited understanding of aquatic organisms, many still understand the relevance of Brook Trout as representing our high-quality resources and a goal for restoration.

Creek Chub and Fallfish rely on flowing water for all life stages, most obviously for reproduction where clean sand and gravels are required for spawning. The free-flowing habitats needed by these species have been highly degraded by impoundments, other physical habitat changes, and water quantity reduction.

The small streams of the state west of the Quabbin Reservoir harbor a number of rare and uncommon species. Longnose Suckers, on the other hand, are fairly widely distributed in the colder rivers and streams of western Massachusetts. Appalachian Brook Crayfish are restricted to only the Hoosic River drainage in northwestern Massachusetts, but they tend to be fairly common in the streams of that watershed. Ocellated Darner dragonflies have mostly been found on the larger rivers (Westfield, Deerfield, Mill) in the Berkshire foothills, but they also venture up small streams.

While the breeding habitats of emerald dragonflies are not well known in Massachusetts, it is thought that four of them – Forcipate, Coppery, Kennedy's, and Mocha Emeralds – all breed in small, slow, boggy streams in central and eastern Massachusetts. Water-willow Stem Borer moths are restricted to southeastern Massachusetts, mostly in ponds and lakes, but where there is Water Willow (*Decodon verticillatus*) along small streams in the southeast, the moth may also be found.

Table 4-17: Species of Greatest Conservation Need in Small Streams

Taxon Grouping	Scientific Name	Common Name
Fishes	*Catostomus catostomus*	Longnose Sucker
	Chrosomus eos	Northern Redbelly Dace
	Cottus cognatus	Slimy Sculpin
	Couesius plumbeus	Lake Chub
	Lethenteron appendix	American Brook Lamprey
	Notropis bifrenatus	Bridle Shiner
	Rhinichthys atratulus	Blacknose Dace
	Rhinichthys cataractae	Longnose Dace
	Salmo salar	Atlantic Salmon
	Salvelinus fontinalis	Brook Trout
	Semotilus atromaculatus	Creek Chub
	Semotilus corporalis	Fallfish
Amphibians	*Lithobates pipiens*	Northern Leopard Frog
Reptiles	*Glyptemys insculpta*	Wood Turtle
	Thamnophis sauritus	Eastern Ribbonsnake
Birds	*Parkesia motacilla*	Louisiana Waterthrush
Snails	*Pomatiopsis lapidaria*	Slender Walker
Crustaceans	*Cambarus bartonii*	Appalachian Brook Crayfish
Mussels	*Anodonta implicata*	Alewife Floater
	Lampsilis radiata	Eastern Lampmussel
	Margaritifera margaritifera	Eastern Pearlshell
Odonates	*Boyeria grafiana*	Ocellated Darner
	Somatochlora elongata	Ski-Tailed Emerald
	Somatochlora forcipata	Forcipate Emerald
	Somatochlora georgiana	Coppery Emerald
	Somatochlora kennedyi	Kennedy's Emerald
	Somatochlora linearis	Mocha Emerald
Lepidoptera	*Papaipema sulphurata*	Water-willow Borer
Plants	*Lycopus rubellus*	Taper-leaf Water-horehound

Threats to Small Streams

As mentioned above, small streams are subject to wide fluctuations in habitat condition and contain flora and fauna that are adapted to deal with some amount of environmental extremity. The threats to small streams will cause changes to water quality and quantity, and to physical habitat that will result in sometimes drastic increases in the frequency and duration of extreme events and a reduction in the ability of the habitat to provide refugia during the events.

Small streams are threatened by land-use practices, fragmentation, and localized impacts of water withdrawal. Impairments to small streams, by the nature of the small watershed, are very local (with the notable exception of acid rain). If a small stream is impacted, the cause is very likely to be nearby. However simple these impacts may seem, they cause cumulative impacts with other downstream impacts and can have a severe impact laterally into floodplain and upland habitats, causing impacts to the species that use those habitats as well.

In small streams, small perturbations can have acute local impacts. One poorly designed parking lot can release enough hot water from a summer thunderstorm to eliminate a coldwater fishery. Removal of riparian buffer strips causes increased exposure to sunlight and increases in temperatures. Unstable soils following removal of riparian cover result in channel modification and increased siltation, creating unstable habitats unsuitable to many of the

SGCN. Likewise, restorations carried out on small streams can also have the most immediate benefits.

Many species that inhabit small streams are tolerant of wide fluctuations found naturally, but cannot adapt to further degradations to already extreme fluctuations. Extreme low flows at natural recurrence intervals can cause population-level effects in Brook Trout that take years to recover from. Water withdrawals that increase the low-flow occurrence interval from 20 years to 3 years will result in populations that never recover. Likewise, exacerbating the extremity of low flows may result in population extirpations requiring more costly restoration efforts.

IUCN Threat 1: Residential and Commercial Development
Impacts from ever increasing amounts of impervious surface in the drainages of small streams can be a major threat to small streams and the aquatic communities they support. Negative impacts to water quality also begin to occur as a greater proportion of total flow must travel over impervious surfaces that may contain pollutants rather than natural ground cover. This also favors generalist species over the specialists that would typically be found in these small streams.

Urban and commercial development adjacent to waterbodies threatens aquatic habitats by altering water quality and physical habitat necessary to support aquatic flora and fauna. Increased impervious surface in the watershed, particularly adjacent to the waterbody, has been correlated to changes in hydrologic functioning, reduced water quality, increased nutrient loading and sedimentation, increased salinization, changes in surface water temperatures, and changes in fish community structure (Armstrong et al. 2011).

IUCN Threat 2: Agriculture and Aquaculture
The greatest threat that agriculture poses to aquatic habitats is nutrient, pesticide, and sediment pollution from runoff, which is assessed below under IUCN Threat 9: Pollution. Livestock farming also poses an increased risk to rivers and streams where livestock are allowed to graze up to, and cross lotic systems, resulting in direct contamination of the waterbody from animal waste, and reducing bank stability. Storage of manure within the floodplain has resulted in washing of animal waste into streams during flooding events. Acute decreases in dissolved oxygen and increases in ammonia from such events have caused localized mussel kills, particularly in habitat of the federally threatened Dwarf Wedgemussel (*Alasmidonta heterodon*). Aquaculture operations can facilitate the transport of exotic organisms, parasites, and diseases into aquatic ecosystems, putting SWAP species at risk.

IUCN Threat 3: Energy Production and Mining
A growing interest in small-scale hydroelectric operations has emerged in recent years as a renewable energy source. Small-scale hydroelectric operations may be exempt from federal regulatory statutes, but do represent potential changes to habitat and water quality affecting SWAP species in small streams.

The extent of gravel mining and quarrying in rivers and streams is currently minimal, but DFW's Natural Heritage & Endangered Species Program has reviewed proposed operations in MESA-species habitat. Streambed quarrying will result in immediate harm to SWAP species, and both acute and long-term habitat degradation. Quarrying and mining in the uplands of a watershed may also increase heavy-metal contamination in aquatic habitats, and alter stream chemistry.

IUCN Threat 4: Transportation and Service Corridors
Road development has had legacy impacts on rivers and streams throughout the Commonwealth. Streams and rivers have been channelized to protect road and stream banks are armored in efforts to minimize bank erosion and migration toward infrastructure. Channelization and hardening of stream banks alters the hydrology and geomorphology of the river, and can reduce the creation of habitat utilized by aquatic invertebrates. Stream crossings, such as bridges and culverts, are often undersized for the size of the stream and result in impounding of water and sediments upstream of the crossing, and may limit habitat connectivity and passage of fish and other aquatic fauna. Increased impervious surface has been correlated to increased salinization, turbidity and temperature changes in surface water, and increases in hydrologic variability (i.e., flashiness). The combined results of these impacts may result in localized or watershed-scale reductions in available habitat for fish, mussels, and other aquatic fauna.

Between 1990 and 2011, there has been a dramatic increase in road-salt usage throughout the northern United States. Average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into adjacent wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations.

IUCN Threat 5: Biological Resource Use

The extent of harvesting of freshwater mussels and odonates in Massachusetts is not well known; however, commercial biological supply operations are known to be collecting freshwater mussels for educational supply, and odonates for educational supply and purported mosquito control. Collection of freshwater mussels for bait is also known to occur, but is not likely an extensive threat to an individual species. There is currently no jurisdictional protection in Massachusetts of invertebrates not listed under MESA, and the effect on fauna may be minimal and localized. Some SWAP fish species are subject to exploitation through harvest for consumption or use as bait species. Both potential exploitation vectors are highly regulated.

IUCN Threat 6: Human Intrusions and Disturbance

Off-road vehicle (ORV) use in riparian areas and within streams can be destructive to physical habitat and reduce water quality. Encroachment into riparian areas by urban activities and development is currently regulated through local conservation commissions, although this regulation is neither evenly applied across the state nor as effective as needed to prevent impairment of small stream habitats.

IUCN Threat 7: Natural System Modifications

Land-use practices that cause immediate deleterious effects to stream biota if Best Management Practices are not followed include forestry, farming, and urbanization. Fill and channelization both remove habitat and alter the function of small streams, making them less capable of supporting small-stream biota. For example, channelization of a trout stream removes bends in streams and consequently the deep scour pools associated with them. These deep scour pools represent the only habitat that might be available in a low-flow event or drought year. Without this habitat, a local reduction in the trout population translates into a larger-scale extirpation. Channelization also impacts floodplain dynamics and soil hydrology, causing a ripple effect through the floodplain-forest, shrub-swamp, and upland-forest habitats as well.

Fragmentation caused by dams, poorly designed culverts, road crossings, and other barriers to fish passage make the habitat less suited to stream species and more suited to other species. Point-source inputs can cause chemical or thermal zones impassible or lethal to fish and other less mobile species. Wells can dewater stream reaches, removing habitat and creating additional barriers to migration or fish movement.

Dams on small streams cause several impacts to aquatic habitats. First, they create habitat unsuitable for native fluvial species but preferred by native and nonnative pond species. Second, they stop the flow and transfer of energy, sediments, and nutrients. Water retained in small stream impoundments warms with increased exposure to sunlight and nutrients trapped in the impoundments become available for macrophyte or algal growth. All of these impacts translate into altered water quality downstream of the impoundment. Third, dams create barriers to fish passage that result in isolated populations of fluvial fish less able to cope with environmental extremes. Finally, most dams have no provision for minimum flow and, other than leakage, provide no flow downstream in the summer months or other low-flow periods. Low or no-flow events then increase in frequency and magnitude and reduce the ability of the fish population to recover. All of these impacts will affect surrounding habitats as well.

Large dams affect freshwater mussels and odonates by altering habitat both below and upstream of the dam, and by limiting the hydrologic connectivity of the river. Impoundments upstream of the dam operate as lacustrine systems; they have altered sediment, hydrology, and temperature regimes that are not conducive to riverine species. River reaches downstream of the dam are often sediment-starved and become incised as the river cuts into its bed rather than spilling out onto its floodplain. Particularly for large hydroelectric dams operating as peaking operations, the reach of river immediately downstream of the dam and bypassed reaches have hydrologic fluctuations at a periodicity that does not favor mussels and riverine odonates that have evolved to tolerate environmental flows that vary by season (Hardison and Layzer 2001). Rapid changes in temperature are also associated with peaking operations and may disrupt one or more critical components in the invertebrate lifecycle (e.g., growth, reproduction, maturation; Gates et al. 2015, Galbraith et al. 2012, Maloney et al. 2012).

Dams of any size may reduce the dispersal of mussel glochidia on their fish hosts. Even large dams with well-designed fish passages are not suitable for passing all fish species. Host fish of some of Massachusetts' rarest unionids (i.e., Dwarf Wedgemussel and Brook Floater) are minnows and/or darters, which are not known to utilize fish ladders and lifts. Other species of mussel (e.g., Tidewater Mucket, Alewife Floater) utilize diadromous fishes, and may be limited in their distribution because their host fish are not provided adequate passage across dams (Nedeau 2008).

Dam removal is becoming an increasingly popular tool for the restoration of stream connectivity, in-stream habitat, and fish passage. While the benefit of dam removal to the function of riverine ecosystems has been well documented, the short-term threats to rare aquatic organism habitat are not always considered. Removal of dams without properly identifying adequate habitat for translocation and monitoring will result in significant losses to the population, and possibly extirpation from that site (Sethi et al. 2004).

Surface water withdrawal for domestic, commercial, and agricultural purposes reduces the available water within aquatic habitat of SWAP species. Loss of water quantity can result in loss of aquatic habitat through drying and reduction in aquatic plants, and will also increase surface-water temperatures, leading to further water quality concerns (i.e., increased risk of algal blooms, decreased dissolved oxygen, or physiological stress on aquatic species).

Annual drawdowns are a form of surface water withdrawal from lakes and ponds for management of nuisance aquatic vegetation. In Massachusetts, winter drawdowns of less than 3 feet serve for adequate protection and management of littoral vegetation, and are considered protective of fish and aquatic invertebrates when specific guidelines are met (Mattson et al. 2004). Following winter drawdown, refill of the reservoir in the spring represents an additional water withdrawal to the receiving waters below the reservoir. This is particularly concerning as stream flows in New England typically reach their highest sustained levels in the spring; thus, most native fauna have adapted to this hydrologic cycle. When winter snowfall is inadequate to recharge the reservoir and groundwater during spring refill, reductions in flow below the reservoir may be significant and affect life-cycle processes of organisms below the dam. In particular, anodontine freshwater mussels (including MESA-listed Dwarf Wedgemussel, Brook Floater, and Creeper) are known to release glochidia in the spring (Nedeau 2008). Reduced spring flows from refill in upstream reservoirs may affect the ability of these mussels to infect host fish and limit recruitment classes. Continued effort is needed to assess environmental flows in receiving waters below reservoirs, lakes, and ponds with deeper drawdowns.

Groundwater withdrawal for agricultural, domestic, and commercial purposes has the potential to affect surface-water volume and temperature in all aquatic habitats. In particular, these events are exacerbated during droughts where surface water and groundwater is not recharged from rainfall. Further reductions in groundwater inputs can result in dewatering of the stream, leading to loss of habitat and changes in physical and chemical water quality parameters to levels unsupportive of native aquatic fauna (e.g., increased temperature, reduced dissolved oxygen, increased salinity).

IUCN Threat 8: Invasive and Other Problematic Species and Genes

The Asiatic Clam (*Corbicula fluminea*) has been increasing in distribution in Massachusetts waters, possibly via recreational fishing boats. While potential threats posed to native bivalves have been identified (Vaughn and Spooner 2006), we are currently unaware of convincing documented evidence that Corbicula pose a significant risk to native unionids. Zebra Mussels (*Dresseina polymorpha*) are established in Laurel Lake (Lee, Massachusetts) and have been found within the Housatonic River downstream of the lake. Zebra Mussels pose significant threats to native unionids when conditions are favorable for expansion (Strayer 2007). The Massachusetts Department of Conservation and Recreation has coordinated a risk assessment of Zebra Mussel invasion through other waterbodies in the state (Nedeau 2010). Water conditions throughout much of the central and eastern parts of Massachusetts are not predicted to be favorable for Zebra Mussel expansion. Nevertheless, continued cooperation with other agencies and occurrence tracking is warranted for these and other introduced aquatic species (e.g., Spiny Waterflea, *Bythotrephes longimanus*; Rusty Crayfish, *Orconectes rusticus*; Robust Crayfish, *Cambarus robustus*).

Beaver play an important role in lotic ecosystems and wetland creation in the state. In a few locations of particularly imperiled mussel species, native environmental engineers like beavers can also pose threats to rare species. North American Beaver (*Castor canadensis*) are nearly fully restored and abundant on the Massachusetts landscape since their extirpation in the 1700-1800s. Where sympatric with Dwarf Wedgemussel and Brook Floater populations, beaver have had a significant yet localized effect on the habitat of these species (Nedeau 2009; David McLain field notes, MA NHESP database). Because of the limited number of populations of these mussels in the state, localized control of beaver populations and water management should be considered as part of site-specific habitat-management plans.

IUCN Threat 9: Pollution
Stormwater runoff has caused substantial changes to water quality and causes erosion issues. Winter runoff often includes high concentrations of road salt, while stormwater flows in the summer cause thermal stress and bring high concentrations of other pollutants. Roads, culverts, public water lines, and sewer lines have created pathways, both intentional (combined sewer overflows [CSOs]) and unintentional (inflow and infiltration), that have expedited the movement of rainfall and runoff into stream channels.

Acidification of waterbodies from atmospheric deposition continues to be a concern throughout the northeastern United States. Alteration of the pH of a waterbody can reduce habitat suitability for sensitive native species. Further, the addition of nutrients from atmospheric deposition (e.g., nitrogen deposition) may also accelerate the effects of eutrophication and change in ecological function of waterbodies in Massachusetts.

IUCN Threat 10: Geological Events
Geological events are not a significant threat to small streams in Massachusetts, at least in the short term.

IUCN Threat 11: Climate Change and Severe Weather
Changes in climate and local weather patterns will likely affect aquatic systems by exacerbating or accelerating habitat degradation due to other identified threats. Increased periodicity and intensity of drought may cause loss of aquatic habitat through short-term drying, but may also concentrate effects of pollutants. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms. Finally, increased runoff from severe storms can damage roads and other infrastructure adjacent to streams. A recent example was Hurricane Irene, which washed out several sections of roads next to Clesson Brook and the Chickley River in western Franklin County, and necessitated a major rebuilding of Route 2 along the Cold River just to the west.

Conservation Actions

Direct Management of Natural Resources
Coordinate with non-profits, educational institutions, USFWS, NRCS Farm Bill programs, municipalities, and landowners to minimize the threat of agricultural animal waste in habitat of SWAP species. Approaches include restoration of riparian buffers and limiting access of livestock to streams.

Identify dam removal as a primary restoration tool and encourage dam removal, where appropriate.

Work with MassDOT, other state agencies involved in habitat restoration, institutions of higher education, and nonprofit organizations to identify and remediate stream crossings to restore connectivity of habitat.

Develop and carry out site-specific management plans to reduce extent and frequency of beaver impoundments in habitat of Dwarf Wedgemussel and Brook Floater. Reassess feasibility and effectiveness of management plan every 5 years in sequence with freshwater mussel rotational monitoring.

Data Collection and Analysis
Conduct research into determining the priorities for restoration of these habitats by examining, in each watershed, the relative impacts caused by the threats listed above (the Meso-Habitat Simulation Model [MesoHabSim]). Work with other stakeholders and research agencies to create habitat-suitability indices for aquatic-invertebrate fauna to better inform the

instream flow needs of rare mussels and odonates in regulated rivers.

Coordinate with Massachusetts Department of Environmental Protection (DEP), and conduct in-house monitoring of water quality in SWAP species habitat.

Surface water and groundwater withdrawals need more research and monitoring on the effects of these actions on water quality in rare-species habitat.

Continue collaboration with USGS Massachusetts Cooperative Fisheries and Wildlife Research Unit to assess the ecological effects of drawdowns on aquatic fauna. Use research to define science-based management policies on extent and periodicity of drawdowns in habitats of SWAP species.

Develop and carry out monitoring and de novo sampling of freshwater mussel and odonate communities throughout the state on a 5-year rotation, where one DFW district is targeted per year. Sites or populations of immediate importance may necessitate deviation from the rotation when immediate threats or need to update information is apparent.

Continue to monitor and complete de novo sampling of SWAP plants associated with this habitat.

Work with other northeastern states to develop standardized freshwater-mussel population-assessment approaches based on previously published methodologies and data reporting to better understand the region-wide threats to mussel conservation.

Continue to work with the Massachusetts Division of Ecological Restoration, The Nature Conservancy, and other interested stakeholders in prioritizing dam removals in sites where MESA-listed species will not be affected. Coordinate and conduct research into the effects of translocation on rare mussel fauna, to help develop dam-removal Best Management Practices in habitats of rare mussels and assess the risks and benefits to MESA-listed species.

Continue to track occurrences of invasive invertebrates during surveys for native species. Encourage data reporting from other agencies, consultants, and academics.

Education and Outreach
Educate and inform the public about the values of small streams and the issues related to their conservation, through agency publications and other forms of public outreach, in order to instill public appreciation and understanding.

Invasive Species: Devise educational material on the importance of proper identification and the potential problems with unintentional or illegal introductions.

Coordinate with town conservation commissions, Massachusetts DEP, and the Massachusetts Lake and Pond Advisory Committee to develop better avenues for reporting of drawdown metrics.

Collaborate with other state agencies toward information sharing and strategic planning on invasive species prevention and control. Work with other state agencies to define invasives of greatest risk, and collaborate as needed to find funding for research and conservation action for species that pose the greatest threats.

Harvest and Trade Management
Identify commercial suppliers and request voluntary information on the species collected and collection sites. Continue to monitor the effectiveness of the existing regulatory framework for protecting SWAP fish species.

Land and Water Rights Acquisition and Protection
Collaborate with other conservation groups for targeted land protection in areas to improve habitat for SWAP species.

Protect land along small streams supporting populations of rare and uncommon animals.

Law Enforcement
Work with the Massachusetts Department of Conservation and Recreation (DCR) and the Massachusetts Environmental Police to reduce informal stream crossings and development of new trails in riparian areas of sensitive habitat on state-protected land.

Provide education to town conservation commissions to ensure proper enforcement and interpretation of the Wetlands Protection Act and the related Rivers Protection Act.

Law and Policy

DFW will continue to review development projects within Priority Habitat of MESA-listed species.

DFW continues to review aquaculture regulations and work with enforcement agencies to ensure that the risks associated with the operation of aquaculture facilities minimizes risks to SWAP species.

Work with state and federal agencies to review and minimize the effects of current hydropower projects and future hydropower development on aquatic species through the Federal Energy Regulatory Commission (FERC) licensing process, the MESA, and the Massachusetts Wetlands Protection Act. Continue to work within the FERC relicensing process and review under MESA and WPA to coordinate instream flows supportive of native aquatic fauna. Coordinate with the Massachusetts Department of Energy Resources (DOER) to develop guidelines and Best Management Practices for small-scale hydropower development in Massachusetts to protect habitat of SGCN.

Work with regulatory agencies to more fully apply existing regulations in buffer areas near streams and to provide guidance to revisions to the regulatory framework to ensure that all appropriate streams are protected.

Coordinate with municipalities and Massachusetts DEP to ensure surface and groundwater withdrawals are within the guidelines of the revised Water Management Act and the Wetlands Protection Act.

Provide methods for using biocriteria (Target Fish Communities) in water quality and quantity standards in Massachusetts.

Coordinate with DCR to include new invasive species on the formal list of Aquatic Invasive Species for regulatory inclusion under the Act to Protect Lakes and Ponds and DCR Regulations under the Aquatic Nuisance Control Program (302 CMR 18.00).

Planning

Develop detailed conservation and recovery plans for SGCN associated with small streams. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Species Reintroduction and Stocking

Population restoration and augmentation of the rarest mussel species may be necessary where habitat is otherwise suitable. Collaborate with other northeastern states, federal agencies, and academic institutions to assess the feasibility of a freshwater mussel propagation facility in New England. Provide technical expertise, research, and conservation direction to the development of restoration and reintroduction methods for freshwater mussels, including identification of refuge habitat for the most critically imperiled species (e.g., Dwarf Wedgemussel and Brook Floater).

Shrub Swamps

Habitat Description

Shrub swamps are shrub-dominated wetlands occurring on mineral or mucky mineral soils that are seasonally or temporarily flooded or saturated. They often occur as a successional area between freshwater marsh and forested swamp (Mitsch and Gosselink 2000) and occur in association with other wetland types in wetland complexes. These wetland shrub thickets are generally flooded in spring and early summer, with water levels dropping below the soil surface by late summer or early fall. Shrubs are perennial woody plants that have multiple stems and are generally less than 20 feet tall. There are usually at most scattered trees in shrub swamps, and the shrubs themselves produce at least 25% ground cover.

Called scrub-shrub wetlands, shrub-carr, alder thickets, and much more, shrub swamps are highly variable communities. The variability comes from effects of different climatic influences, topography, hydrologic regimes, amount and types of mineral enrichment in surface- and groundwater, and particularly from the effects of past land use, all of which confuses the interpretation of succession and direction. Shrub swamps can be dominated by one of, or a few of, or have a mixture of, the following shrub species: alders, Sweet Pepper-bush, Buttonbush, Winterberry, Highbush Blueberry, Swamp Azalea, Maleberry, dogwoods, arrow-woods, Meadowsweet, Sweet Gale, willows, Poison Sumac, Common Greenbrier, and the nonnative European alder-buckthorns. Scattered Red Maple or Gray Birch saplings also occur. Shrub swamps in areas with circumneutral water are often dominated by Spicebush. Willows are particularly common in swamps with more calcium-rich waters.

Buttonbush swamps are probably the wettest shrub swamps, many staying permanently saturated year-round. They occur on the edges of ponds and lakes or next to deep marshes; others are in smaller isolated depressions. Water-willow is another shrub species that is usually found in permanently saturated or areas that remain flooded year-round.

Shrub swamps are often found in areas of transition from either uplands or open water to peatland habitats. In areas with calcium-rich water where peat is not well developed, shrublands are particularly found in transitional areas. Many such areas are mosaics of patches of shrubs and more open sedges or cattails. Dense shrub zones often develop around the edges of bogs where mineral water influence keeps peat from developing.

Shrub swamps often occur in association with and succeed to forested swamps. In areas with active beaver populations, as dams are abandoned after beaver food resources (primarily deciduous/ hardwood tree bark and twigs) become depleted, the impoundments drain, and succeed first to wet meadow, and then to shrubland and early-successional forest. Beaver then reoccupy such low-lying sites, and continue the process of restarting succession and the cycle of habitat modification. This process has been much reduced now that many low-lying areas are occupied by people who control or reduce the natural processes associated with flooding regimes. In presettlement times, beaver were, and they continue to be, particularly important in maintaining streamside, or alluvial, shrub swamps.

Other areas that support shrub swamps include kettleholes that receive frost late enough in the spring to kill tree species. Many kettleholes, on the other hand, develop peat and support acidic shrub fens or bogs (often with shrub swamps around the edges). Humans often maintain powerline rights-of-way in shrub cover; in such sites, wet areas become and are kept as shrub swamps.

Since shrubs often form dense thickets, the herbaceous layer of shrub swamps is often sparse and species-poor. A typical mixture of herbaceous species might include Skunk Cabbage, various ferns (especially Cinnamon Fern, Sensitive Fern, and Royal Fern), sedges, and sphagnum moss, with Common Arrowhead in wetter areas. Water-willow grows in the more open areas of shrub swamps.

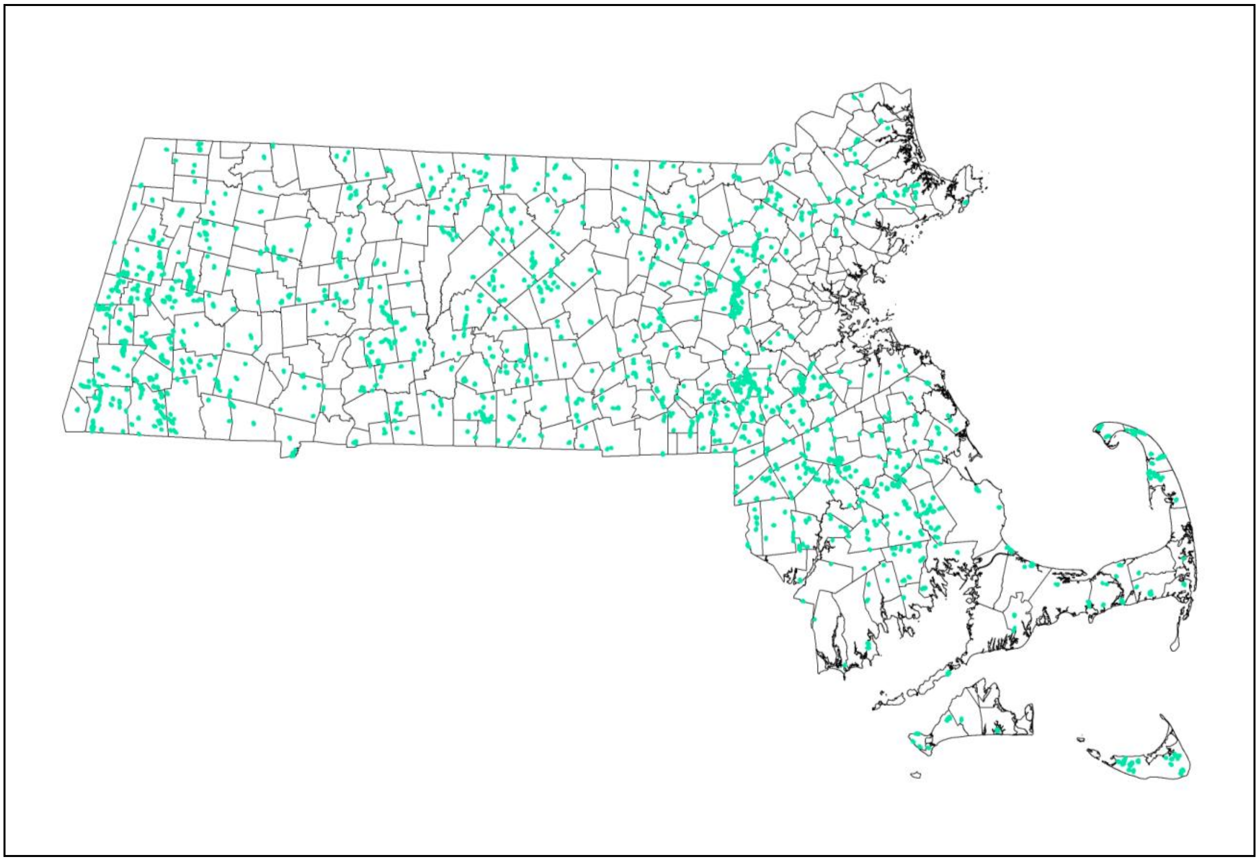


Figure 4-23: Larger Shrub Swamps (10 acres or more) in Massachusetts.

These data were derived from the MassGIS DEP wetlands datalayer.

Species of Greatest Conservation Need in Shrub Swamps

Twenty-three SGCN are assigned to the Shrub Swamps habitat (Table 4-18).

Shrub swamps provide some of the most productive breeding habitats for amphibian SGCN in Massachusetts. Many shrub swamps function hydrologically like vernal pools, and they provide some of the highest-quality vernal-pool habitats. Thus, although vernal pool obligate breeders, such as the SGCN mole salamanders, are categorized into the SWAP Upland Forests and Vernal Pools Habitats for the purposes of this plan, it is important to recognize the value of shrub swamps for these species. The relatively long hydroperiods of the swamps ensure that amphibian larvae have plenty of time to develop to metamorphosis, and the diverse vegetation structure provides both cover for larvae and egg-attachment substrates for breeding adults. Buttonbush swamps seem to be a preferred breeding habitat for Blue-spotted Salamander and are known to support relatively large numbers of breeding Jefferson Salamander and Marbled Salamander, as well. Buttonbush swamps associated with river floodplains support breeding populations of Northern Leopard Frog.

Optimal Bog Turtle habitat is a mosaic of open habitat with rivulets beside tussocks, surrounded by successional stages of freshwater marsh and shrub swamp. Patches of calcareous sloping fens or calcareous seepage fens mixed with large areas of shrub swamp make good habitat for several rare turtles, providing basking areas near thickets. Beaver-influenced shrub swamps provide particularly important habitat for the Blanding’s Turtle. Other mosaic wetlands with shrub swamps also provide good turtle habitat. Turtles utilize a variety of seasonal habitats, including multiple wetland habitat types, throughout their life cycle.

Shrub swamps with semi-permanent standing water, such as buttonbush swamps, provide good cover for a variety of ducks such as the American Black Duck and other waterfowl, including the Common Gallinule. Large shrub swamps, especially in central and western Massachusetts, often support breeding American Bittern. Shrub swamps provide important breeding habitat for many species of migratory birds, which make use of the dense thickets as protected nesting habitat. The hydrologic regime in shrub swamps will greatly influence their use by American Woodcock; as they probe the soil for invertebrates, there is a finite period when soil conditions are conducive to efficient foraging.

In the winter when the surface is frozen, browsers, including New England Cottontail, have easy access to the shrubs and protection in the dense thickets. The dense shrub component provides significant cover essential to this species that suffers very high natural predation, particularly in the winter. The amount of water within one kilometer of an occupied habitat patch has been linked to higher survival (Brown and Litvaitis 1995). Within the past decade, winter survey work for New England Cottontail has documented their occurrence in wetland complexes that include shrub swamps in association with forested swamps. The abundance of woody browse is clearly very important for them.

The larvae of the Pale Green Pinion feed on a variety of shrubs in acidic shrub swamps on the coastal plain. Another moth restricted to southeastern Massachusetts, the globally rare Precious Underwing, feeds as a larva on chokeberries (*Aronia* spp.) in acidic shrub swamps. Two species in the herbaceous layer of shrub swamps, Virginia Chain-fern (*Woodwardia virginica*) and Water-willow (*Decodon verticillatus*), are larval hosts for the Chain-fern Borer and the Water-willow Borer. Three additional SGCN moths inhabiting shrub swamps, all feeding as larvae on blueberries (*Vaccinium* spp.), are the Heath Metarranthis, Slender Clearwing, and Chain-dotted Geometer.

Several of the plant SGCN associated with shrub swamps, including Swamp Birch, Showy Lady’s-slipper, and Labrador Bedstraw, are calciphiles and only grow in areas of calcareous groundwater seepage. Both Bartram’s Shadbush and One-flowered Pyrola are found in cool, moist, coniferous habitats. All are sensitive to changes in the hydrology of their habitat, including anthropogenic activities and beaver dams. Some plant species, such as Bailey’s Sedge, are tolerant of and thrive with some disturbance in their immediate habitat, but mature canopy and full shade will eliminate the species.

Table 4-18: Species of Greatest Conservation Need in Shrub Swamps

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Clemmys guttata*	Spotted Turtle
	Glyptemys muhlenbergii	Bog Turtle
	Emydoidea blandingii	Blanding’s Turtle
Birds	*Anas rubripes*	American Black Duck
	Buteo platypterus	Broad-Winged Hawk
	Scolopax minor	American Woodcock
Mammals	*Sylvilagus transitionalis*	New England Cottontail
Lepidoptera	*Catocala pretiosa pretiosa*	Precious Underwing
	Cingilia catenaria	Chain-dotted Geometer
	Hemaris gracilis	Slender Clearwing
	Lithophane viridipallens	Pale Green Pinion
	Metarranthis pilosaria	Heath Metarranthis
	Papaipema stenocelis	Chain-fern Borer
	Papaipema sulphurata	Water-willow Borer
Plants	*Amelanchier bartramiana*	Bartram's Shadbush
	Betula pumila	Swamp Birch
	Carex baileyi	Bailey's Sedge
	Cypripedium reginae	Showy Lady’s-slipper
	Galium labradoricum	Labrador Bedstraw
	Lygodium palmatum	Climbing Fern
	Moneses uniflora	One-flowered Pyrola
	Pedicularis lanceolata	Swamp Lousewort
	Rumex verticillatus	Swamp Dock

Threats to Shrub Swamps

IUCN Threat 1: Residential and Commercial Development
Development pressure in Massachusetts is high. Relatively strong environmental regulations in the state (e.g., the Massachusetts Wetlands Protection Act) are effective in safeguarding most shrub swamps from physical loss to residential and commercial development. However, shrub swamps that are small, isolated, and relatively inconspicuous are vulnerable to being overlooked, and terrestrial habitats surrounding shrub swamps have few legal protections outside of the MESA legislation.

Land development that involves clearing, grading, filling, and/or building-construction and associated landscaping may result in the direct filling and permanent physical loss of shrub swamp habitat. Blasting activities downslope of shrub swamps can break perched water tables from below and, therefore, permanently destroy the hydrologic function of affected swamp basins. Increased impervious surface in the watershed, particularly in areas adjacent to a basin, may result in altered hydrologic function, reduced water quality, increased nutrient-loading and sedimentation, increased salinization, and/or changes in surface water temperatures (Snodgrass et al. 2008). Both increases and decreases in the water within a shrub swamp will alter the vegetation, including SGCN plants. Mole salamanders (e.g., Jefferson Salamander, Blue-spotted Salamander, Marbled Salamander) that breed in shrub swamps also require the terrestrial habitats surrounding the swamps to complete their life cycles. Hence, the breeding-habitat function can be indirectly disrupted when residential and commercial developments destroy those terrestrial habitats (Homan et al. 2004). When development occurs in the immediate vicinity of shrub swamps and/or creates physical barriers between them, the ability of organisms to access and populate those swamps is impaired, thus affecting the habitat function of the swamps and the metapopulation dynamics of associated SGCN.

Habitat fragmentation associated with development poses a significant threat to shrub-swamp-associated species that move across the landscape, such as Blanding’s Turtle and Blue-spotted Salamander (deMaynadier et al. 2008; Jones and Sievert 2012; Reid and Peery 2014). Fragmentation in developed landscapes can also pose a threat to foraging behavior and dispersal for species such as New England Cottontail, which are more vulnerable to increased predation in open areas without the escape cover offered by shrub habitats (Brown and Litvaitis 1995; Smith and Litvaitis 2000). Fragmentation also impedes shrub swamp plants from seeding in or otherwise colonizing nearby appropriate habitats.

IUCN Threat 2: Agriculture and Aquaculture
Pressure from agricultural development in most parts of Massachusetts is relatively low, and demand for “green” (e.g., organic) products from existing operations is relatively high. However, certain types of agricultural activities are exempt from most environmental regulations in Massachusetts, including the Wetlands Protection Act. Furthermore, the limited exemptions are sometimes perceived by landowners as unlimited, blanket exemptions, and so unlawful loss of shrub swamps (or portions of shrub swamps) to agricultural development does occur on occasion.

Agricultural development involving clearing, grading, and/or filling may result in the direct filling and permanent physical loss of shrub swamp habitat. Agricultural dumping may physically and/or chemically alter shrub swamps. Runoff from agricultural fields may negatively alter soil and water chemistry and, therefore, harm associated amphibians via introduction of fertilizers, pesticides, and/or herbicides (Rouse et al. 1999; Burgett et al. 2007; Baker et al. 2013).

As both Spotted Turtles and Blanding’s Turtles frequently nest at anthropogenic features such as agricultural fields and cranberry bogs (Beaudry et al. 2010), agricultural activity poses a potential threat of adult mortality and nest loss (Erb and Jones 2011). At the same time, agriculture and other human activity may create important nesting habitat, so the effects of agriculture on these species is mixed and not well understood. Benefits and threats due to agricultural activity may be present for New England Cottontail. Habitat use by them was shown to shift from dense cover in winter to more open areas and agricultural fields in the summer (Cheeseman, 2015, personal communication).

IUCN Threat 3: Energy Production and Mining
Energy production and mining pressure in Massachusetts is probably considered moderate. Despite relatively strong environmental regulations in

the state, energy production is a high-ranking public need, and some long-established sand/gravel mining operations are not always subject to more recently established regulations and/or permitting requirements. Energy production, such as solar arrays, wind turbines, and plants of various types, and sand/gravel mining tend to be relatively localized threats, but they are probably significant to shrub swamp ecology where they occur (especially with respect to smaller swamps). Furthermore, terrestrial habitats surrounding shrub swamps are highly vulnerable, as there are few legal protections for those areas besides the MESA legislation.

Energy production and/or sand/gravel mining activities that involve clearing, grading, and/or filling may result in the direct filling and permanent physical loss of shrub swamp habitat. Blasting activities downslope of shrub swamps can break perched water tables from below and, therefore, permanently destroy the hydrologic function of affected swamp basins. Mole salamanders (e.g., Jefferson Salamander, Blue-spotted Salamander, Marbled Salamander) that breed in shrub swamps also require the terrestrial habitats surrounding the swamps to complete their life cycles. Hence, the breeding-habitat function of a swamp can be indirectly disrupted when energy production and/or mining activities destroy adjacent terrestrial habitats. Sand and gravel pits can provide nesting habitat for turtles, but can also pose a threat of increased mortality and nest failure (see Threat 2, above). When large-scale mining activities occur in the immediate vicinity of shrub swamps and/or create physical barriers between them, the ability of organisms to access and populate those swamps is impaired, thus affecting the habitat function of the swamps and the metapopulation dynamics of associated SGCN.

IUCN Threat 4: Transportation and Service Corridors
Shrub swamps receive substantial regulatory protection from direct loss to development of new transportation and service corridors in Massachusetts, via the Massachusetts Wetlands Protection Act. However, terrestrial habitats surrounding shrub swamps are quite vulnerable, as there are few legal protections for those areas besides the MESA. There are few to no regulatory protections for shrub swamps with respect to pollution from road/highway runoff, or with respect to the alteration of swamp ecology caused by road-related animal mortality and habitat fragmentation.

Density of transportation and service corridors in Massachusetts is relatively high, and so the threat of development of new corridors is relatively low in most parts of the state. However, several proposed corridors may be highly ranked public needs, and some shrub swamps may ultimately be lost, impaired, or altered as a result of their development. Pollution associated with road/highway runoff is a continuing concern for many swamps and a cause of decline of SGCN plants within shrub swamps, and mortality of dependent organisms attempting to cross roads is considered a major threat to swamp ecology throughout much of the state.

With roads come an increase in road salt, and its associated components, chloride in particular. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into adjacent wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations.

Existing transportation and service corridors (e.g., roads, highways, railways) often act as physical barriers to movement and/or sources of adult mortality for organisms (e.g., salamanders, turtles) that use shrub swamps and must traverse terrestrial habitat to access them (Gibbs 1998; Gibbs and Shriver 2005; Andrews et al. 2008; Bartoszek and Greenwald 2009; Sutherland et al. 2010). Roads or highways with high traffic volume also create noise pollution, which may alter breeding behavior (e.g., frog calling) in nearby wetlands in ways that either impair breeding activity (Tennessen et al. 2014) or result in certain tradeoffs that could conceivably reduce reproductive fitness (Parris et al. 2009; Cunnington and Fahrig 2010). In addition, transportation corridors are sources of chemical pollution for many shrub swamps in Massachusetts, as storm runoff from roads and highways introduces metals, salts, oils, and other compounds to swamps, thus altering swamp chemistry and, in some cases, impairing or destroying the biological function of the habitat (Turtle 2000; Croteau et al. 2008; Karraker et al. 2008; Brady 2012). Hence, existing transportation and service infrastructure may indirectly impact shrub swamp habitat by limiting or reducing local biodiversity (Fahrig and Rytwinski 2009). Maintenance of service corridors (e.g., gas-line and power-line rights-of-way) can alter vegetation composition and structure in shrub swamps occurring within the corridors, or modify light conditions at swamps bordering corridors; those types of impacts are generally considered relatively minor, however.

Development of new transportation and service corridors involves clearing, grading, and/or filling, which can result in direct filling and permanent physical loss of shrub swamp habitat. Blasting activities downslope of shrub swamps can break perched water tables from below and, therefore, permanently destroy the hydrologic function of affected swamp basins. Once established, transportation and service corridors threaten shrub swamp habitat as described in the preceding paragraph.

In Massachusetts, analysis of 272 road-kill rabbit carcasses collected between 2009 and 2013 from locations where New England Cottontail and the introduced Eastern Cottontail both occur resulted in only 18 New England Cottontail mortalities, while 247 were Eastern Cottontails. The remaining were either Snowshoe Hare or unidentified. It is unknown if New England Cottontail avoid crossing roads to forage in or disperse to suitable habitat. Utility corridors including powerlines and pipelines may serve to facilitate dispersal of New England Cottontail from forested swamp habitat to other suitable areas.

IUCN Threat 5: Biological Resource Use
Some SGCN (e.g., Bog Turtle, Blanding's Turtle, Spotted Turtle, Showy Lady's-slipper) that use shrub swamps are poached for trade or other illegal uses, and the risk of ad hoc collecting facilitated by chance encounters with turtles and showy flowers likely increases as habitat fragmentation and human populations increase. The magnitude of the problem in Massachusetts is unknown, but poaching is of great concern regarding globally rare SGCN (e.g., Bog Turtle).

Timber harvesting (logging) is a common land use in most parts of Massachusetts (except for Cape Cod). Logging can impact shrub-swamp ecology in a number of ways, not all of which are well understood (deMaynadier and Houlahan 2008). Logging removes portions of the forest canopy and, therefore, alters light conditions, water temperature, organic inputs, and nutrient cycling in and around wetlands. Logging also compacts soils and may introduce nonnative invasive plants to the terrestrial habitat immediately surrounding a shrub swamp. Establishment of logging roads or trails adjacent to or through swamp basins can create problems with erosion and runoff, thus impacting water quality. Overall, logging is considered a relatively minor threat to shrub swamps in Massachusetts; other than the problem of nonnative invasive plants, logging-associated impacts to shrub swamps are typically minor, temporary, and/or minimized by regulatory protections (e.g., the Forest Cutting Practices Act regulations [304 CMR 11.00]).

IUCN Threat 6: Human Intrusions and Disturbance
An unknown percentage of shrub swamps in Massachusetts are impacted by human intrusions and disturbance. The most commonly observed disturbances are dumping, intentional filling, operation of off-road vehicles (ORVs), and biological surveys. Generally, small shrub swamps are most vulnerable.

Dumping activity, as evidenced by the types of old cars and household appliances found in swamps, appears to be less substantial now than in decades past. However, dumping of trash, tires, brush, and lawn clippings is an ongoing threat to shrub swamps located near roadside pull-offs, trailheads, and suburban yards. Intentional filling with tree limbs, leaves, and other yard waste by landowners attempting to manage surface water on or adjacent to their properties is an occasional problem. The degree to which dumping and filling impact shrub swamps varies by locality, but smaller basins in areas of greater human population density tend to be most at risk. Most shrub swamps are legally protected from dumping/filling, but detection of violations and/or identification of violators can be difficult.

Operation of ORVs in shrub swamps having open basins is a common occurrence along electric transmission line rights-of-way and is a problem on some public lands in Massachusetts. Most such ORV use is illegal, but enforcement of relevant laws is difficult. Hence, chronic physical disturbance from ORV operation is a threat to shrub swamps along most electric-transmission-line corridors and on some public lands.

Relatively open shrub swamps located on public lands and resembling vernal pool habitat are threatened by human disturbance via excessive biological surveying. There is high demand for public open space in Massachusetts, and some swamp basins are surveyed multiple times per year for various recreational, educational, and/or scientific endeavors. Some types of surveys (e.g., log/rock-rolling, dip-netting) are disruptive to microhabitats within swamp basins, while others (e.g., funnel-trapping) are disruptive to breeding activity of organisms using the swamps. Repeated disturbance of shrub-swamp basins appears most problematic on lands near large population centers (e.g., Boston, Springfield) and in areas where public land is in relatively low supply. The magnitude of the impacts to shrub swamp organisms has not been studied in Massachusetts, but physical alterations to swamp microhabitats are apparent and could presumably harm their biological function. Human-caused spread of pathogens and disease among shrub swamps is an additional threat to vernal-pool ecology.

IUCN Threat 7: Natural System Modifications
The main threat to shrub swamps is alteration of the hydrological regime. Changes in either surface water or groundwater alter the flooding regime and the minerals and nutrients carried to shrub swamps, and can change the wetland status and the species present. Change in hydrology is the greatest threat to most of the plant SGCN. All of these plant species have evolved to specific hydrologic regimes, and changes in water level will impact whether the plant will be able to survive. When shrub swamps occur adjacent to open water of lakes or streams, the shrubs are sometimes removed to allow or improve human access to the water for recreation.

Abstraction of groundwater and surface water (e.g., from streams) for residential, commercial, and agricultural use could potentially threaten small shrub swamps in Massachusetts. Substantial abstractions during droughty conditions for residential and agricultural irrigation or commercial snow production could contribute to low water tables and, therefore, shorten periods of inundation and soil saturation in area swamps. This threat is under-investigated in Massachusetts, and so its magnitude is unknown.

Most types of shrub swamps are successional and need regular disturbance to be maintained in place, or they are maintained as parts of a larger area by disturbances moving over the landscape in time and space. Reduction in beaver activities reduces areas of early succession where shrub swamps develop. Conversely, long-term occupation of a site by beavers can result in flooding, establishment of a semi-permanent hydroperiod, and loss of the shrub layer for decades or longer. Such areas of flooding are likely to affect plant SGCN, including Climbing Fern, Swamp Lousewort, and One-flowered Pyrola, which have already been impacted by beaver dams and flooding within their habitats.

Wetland loss and hydrologic alterations pose potential threats to Blanding's and Spotted turtles. Although Blanding's Turtles occupy a variety of wetland types, their core wetlands in Massachusetts often include beaver-influenced shrub swamps and deep marshes. Historically, Blanding's Turtles most likely moved across the landscape in response to hydrologic changes associated with beaver activity. As landscapes are increasingly fragmented, beaver control and beaver-dam removal pose a potential threat to Blanding's Turtles, as they may have less suitable habitat available and greater risk of road mortality, as they move across the landscape.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Water-level disturbance can lead to invasion by nonnative plants, including the aggressive exotics Purple Loosestrife (*Lythrum salicaria*), Tatarian Honeysuckle (*Lonicera tatarica*), Morrow's Honeysuckle (*Lonicera morrowii*), and Glossy Buckthorn (*Frangula alnus*). Common Reed (*Phragmites australis*) is also an aggressive exotic in disturbed shrub swamps. Swamp Birch and Labrador Bedstraw are both particularly vulnerable to shading and overgrowth by Common Reed and Purple Loosestrife.

Particular shrub species can be preferentially selected by deer for browsing, with a resulting change in composition and structure of vegetation when deer populations are high. Heavy browsing by deer has been shown to prevent reproduction of chokeberry shrubs after fires and logging (NatureServe 2005), which is particularly detrimental to the Precious Underwing. Deer are also a primary threat to the Showy Lady's-slipper, as they appear to target the flowers as forage.

Emerging infectious disease is currently considered one of the greatest threats to global biodiversity, and amphibians are an especially vulnerable group. Although amphibians in the New England region appear to be relatively resistant to some pathogens that are problematic elsewhere in the world (e.g., the chytrid fungus *Batrachochytrium dendrobatidis* [*Bd*]; Longcore et al. 2007; Richards-Hrdlicka et al. 2013), there is suspicion that other pathogens such as ranavirus have caused recent mass-mortality events in vernal pools of the region (Wheelright et al. 2014), including Massachusetts. Since many shrub swamps function as vernal pool habitat for amphibian SGCN and are utilized by other amphibian species known to be carriers of ranavirus (e.g., Green Frog), shrub-swamp ecology is vulnerable to impacts of the spread of emerging infectious disease. Of particularly grave concern is the potential for future introduction and spread of the salamander fungus *Batrachochytrium salamandrivorans* (*Bsal*), known best for its devastating impacts on amphibians in Europe (Martel et al. 2014).

The potential spread of pathogens among shrub swamps may be facilitated by animal commerce, illegal animal translocations, use of contaminated field gear during biological surveys, and natural dispersal of native fauna (Picco and Collins 2008; Gray et al. 2009). Infection rates and long-term impacts to shrub swamps and their associated organisms are understudied in Massachusetts. However, ranavirus is known to affect or be carried by a wide variety of taxa (e.g., frogs, salamanders, turtles, fish), and research findings in other parts of the country suggest that it can have severe, acute impacts on amphibians (Gray et al. 2009; USGS 2012; Brenes et al. 2014; Currylow et al. 2014). Given the great difficulty of controlling the spread of pathogens and the lack of knowledge about persistence and long-term consequences of local outbreaks, emerging infectious disease must be considered a major threat to shrub-swamp ecology in Massachusetts. Relatively small shrub swamps are likely the most vulnerable.

New England Cottontails occupying habitats with a greater percent of invasive plant species had more parasites (Gavard 2015, personal communication). In addition, although the decline in New England Cottontail corresponds with the introduction of Eastern Cottontail, interactions between the two species are unclear. Some data indicate segregation of habitat in locations where both species occur (Cheeseman 2015, personal communication; Kovach, Papanastassiou, Kristensen 2015, personal communication).

IUCN Threat 9: Pollution

Shrub swamps are vulnerable to nutrient loading and/or chemical contamination when they are adjacent to lawns, golf courses, cropfields, parking lots, roads, gas stations, and other areas where accidental spills or deliberate applications of chemicals occur (Snodgrass et al. 2008). Surface runoff from those areas can introduce contaminants to swamps, thus altering water chemistry and impairing biological function (Burgett et al. 2007; Croteau et al. 2008; Baker et al. 2013). Of particular concern is the threat of road deicing salts to amphibian reproduction (Turtle 2000; Karraker et al. 2008; Karraker and Gibbs 2011; Brady 2012). Calcium chloride contamination of groundwater has been increasing; see the discussion under IUCN Threat 4. Shrub swamps are typically afforded 100-foot terrestrial buffers (via the Massachusetts Wetlands Protection Act) to mitigate the threat of contamination by runoff, but those regulatory protections do not apply to land uses that were in place prior to enactment of the legislation. Given the high human-population density in Massachusetts, many shrub swamps are impacted by contamination via surface runoff. Acidification of shrub swamps is a concern where they function as breeding habitat for amphibian SGCN, especially Jefferson Salamander and Northern Leopard Frog. Low pH (e.g., less than 4.5) can inhibit embryonic and larval development and survival, thereby reducing reproduction and recruitment (Freda and Taylor 1992; Karns 1992; Sadinski and Dunson 1992). Increases in acid precipitation may alter water chemistry in smaller shrub swamps slowly over time, or particularly heavy precipitation events may trigger sudden spikes in aluminum, which is toxic to larval amphibians (Jackson and Griffin 1991; Horne and Dunson 1995; Croteau et al. 2008).

Aerial insecticide spraying is a potential threat to insects in active life stages (larva or adult) at the time of pesticide application (Emmel and Tucker 1991). In years with an outbreak of Eastern Equine Encephalitis (EEE), insecticides are sprayed across large areas of wetland habitat in eastern Massachusetts, including shrub swamps. Aerial insecticide spraying for EEE typically occurs in late summer and early fall, and the targets are the mosquito vectors of this disease. Unfortunately, such insecticide application may cause significant mortality of non-target insects (Emmel and Tucker 1991), including shrub-swamp SGCN species that are active in late summer and early fall. Such species include the Water-willow Borer, Chain-fern Borer, Heath Metarranthis, and Chain-dotted Geometer. Nontarget insects affected may also include important food sources for both invertebrate and vertebrate predators, such as Blue-spotted Salamander larvae.

Pollution in the limited number of alkaline seepage shrub swamps in Massachusetts could threaten populations of Showy lady's-slipper and Swamp Birch.

IUCN Threat 10: Geological Events

Geological events are not a major threat to shrub swamps in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Climate-change analyses project varying scenarios for the northeastern United States. Although total precipitation is expected to increase, other common predictions include warmer temperatures, longer and more severe summer droughts, shorter but more intense winter/spring floods, and reduced extent and duration of winter snow cover. Taken together, such changes could alter the hydrological regimes of many shrub swamps in the region. Expected outcomes include seasonal drying of wetland soils, which could facilitate changes in dominant vegetation. Smaller shrub swamps could be lost entirely, while larger ones could contract in area or become fragmented. There is the possibility of a net gain in amount of shrub-swamp habitat, as edges of open-water wetlands might convert to shrub swamps as woody vegetation invades shallower and more ephemerally inundated areas. Recent research indicates that the last two decades have been the wettest years in the Northeast in 500 years (Pederson et al. 2013; Newby et al. 2014; Weider and Boutt 2010). This has led to higher groundwater elevations and may lead to an increase in the extent of this habitat, but areas of lower elevation in the current extent of the habitat may flood, changing the current vegetation in those areas.

Many amphibian and reptile species have poor dispersal capabilities in landscapes with high road densities, such as Massachusetts, and so the spatial relationships between lost shrub swamps and new ones will be important to take into consideration when predicting habitat availability to some SGCN. Climate change poses significant threats to local populations of SGCN that currently rely on smaller shrub swamps in landscapes having poor connectivity with larger swamps and/or open-water wetlands.

The Conservation Strategy for the New England Cottontail determined climate change will not be a threat. However, for a species with limited dispersal capabilities, shifting of available habitat that results in a loss of shrub swamps could pose a threat, while an increase in the amount of available shrub habitat along the edges of open water could be beneficial.

Bartram's Shadbush is near the southern extent of its range in Massachusetts and a warming climate may threaten this species in the state.

Conservation Actions

Direct Management of Natural Resources
Restoring and managing selected shrub swamps to maintain appropriate successional stages by introducing appropriate disturbance regimes (fire, mowing, grazing, etc.) is important to maintain the structure and species composition of some shrub-swamp habitats. Applying a disturbance regime should only be undertaken if there is a demonstrated need for this management. Some critically important marshbird habitat in Massachusetts is a direct result of water-level manipulation, especially at impoundments on wildlife refuges behind flood control structures. Impoundments that support significant populations of state-listed and other SWAP species should be managed in a way that is conducive to perpetuating these populations.

Addressing invasive species in shrub swamp habitats at important habitat areas for SWAP species is a priority conservation action. Programs to proactively treat established invasive species are key to restoring important habitats and should be pursued whenever possible. Protocols to prevent the establishment of invasive species, either through controlling potential vectors (contaminated soil, landscaping, etc.) or addressing pioneering invasive populations through early-detection—rapid-response programs, are important ways of dealing with invasive species before they are impacting a habitat.

The DFW has developed Best Management Practices for controlling the spread of invasive species. This involves thoroughly cleaning the exterior, undercarriage, and tires/tracks of equipment being used for habitat management with a high-pressure washer prior to arriving on a property, to reduce the risk of invasives being carried onto a site from other locations. Following these is required for contractors working on the Division's land and recommended for management projects taking place on private, land trust, and other state or federal lands.

The Division works under formal partnership with the USDA's Natural Resources Conservation Service to plan habitat management projects on privately owned land aimed specifically at benefitting SWAP species. Projects are funded through United States Department of Agriculture Farm Bill Programs. Management activities may include invasive-species control or removal of encroaching canopy trees to maintain successional characteristics of shrub swamps. Under the 2014 Farm Bill, the Environmental Quality Incentives Program includes Working Land for Wildlife funding directed specifically at managing habitat for New England Cottontail and Bog Turtle. In Massachusetts, this funding has been used on private land to control shrub swamp succession and treat invasive *Phragmites* in shrub swamps identified as habitat for Bog Turtle. Funding for these kinds of projects, whether on private or conserved lands of all sorts, should be continued and expanded.

Roads and rail-lines have the potential to serve as barriers to turtle movement and a significant source of mortality (Steen et. al 2006). Wildlife collisions may also impact other wildlife species such as Black Bear and Moose (Fahrig and Rytwinski 2009), and can pose a significant threat to public safety. To address this issue, the Division worked with MassDOT to develop an important new program called Linking Landscapes for Massachusetts Wildlife (http://www.linkinglandscapes.info/). This program works with volunteers and conservation professionals to identify hotspots of turtle and wildlife mortality and to remediate threats and improve landscape connectivity through the installation of crossing structures and barriers. This program is ongoing and should continue into the future. The Division also worked with MassDOT to develop a novel turtle crossing structure between modified railroad ties that could have important applications elsewhere (Pelletier et al. 2005). More research is needed into the effects of roads and rail lines on the movement ecology of a variety of species, including SGCN turtles and salamanders. Future conservation actions could involve work with MassDOT, municipal departments of public works, and others to manage beaver to protect key infrastructure, while simultaneously protecting key habitat features for species such as Blanding's Turtle.

Data Collection and Analysis
Biological inventory and monitoring of shrub swamps are necessary to identify and understand distribution and abundance of associated SGCN. This could be done by locating large shrub swamps statewide via aerial photo-interpretation, and then field-surveying a selected percentage of these swamps for rare or uncommon animals and plants, as well as locating smaller shrub swamps and field-surveying a subset for comparisons of use by rare or uncommon animals and plants. Data generated by such surveys are critical to establishing and maintaining site-specific regulatory protections for SGCN and to developing effective, long-term conservation plans for the species. Biological-inventory data are needed to assess the basic population status of some SGCN, answer outstanding questions about population genetics, or even confirm suspected species identities (for example, certain local populations of leopard frogs).

Shrub swamps function as population centers for several SGCN and, therefore, are natural sites for studying fundamental aspects of the species and improving our knowledge about how to study them more effectively. Investigations into population genetics, microhabitat preferences, metapopulation dynamics, and survey efficacy are examples of research that will help inform conservation planning and associated actions. One priority is to work with conservation partners to improve understanding of the genetic structure of salamander populations in the Jefferson/Blue-spotted salamander complex. Preliminary findings from an earlier study suggest that such work could play a major role in prioritizing sites for conservation.

Long-term monitoring of shrub swamp hydrology, chemistry, pathogen loads, and associated SGCN demographics as part of a larger vernal pool and other wetland monitoring program is needed to detect, understand, and act on SGCN population trends at both local and state scales. Such a program would be especially beneficial in understanding and planning for impacts associated with climate change, emerging infectious disease, pollution, and habitat loss/fragmentation. Comparing vulnerabilities of classic vernal pools with certain classifications of shrub swamp that act as vernal pools would provide useful information in assessing overall threats to certain SGCN that utilize multiple habitat types.

Threats associated with transportation and service corridors will need to be addressed by identifying road mortality hotspots for target species, working with MassDOT to remediate them when practical, continuing to support research into wildlife-crossing design, and continuing to implement standardized long-term monitoring of turtle populations to detect regional and statewide trends.

Marshbird populations are dynamic and a survey of the state's shrub swamp habitats is needed to evaluate status and conservation needs. Systematic call-and-response surveys targeting representative shrub swamps across the state should be undertaken to determine species' current populations and distributions, as well as to identify important management needs.

Habitat modeling for New England Cottontail indicates wetland complexes that include shrub swamps have high suitability for the species, and survey work has been focused in these areas in the Southern Berkshires. In some locations, New England Cottontail has persisted for at least 10 years in unmanaged wetland complexes that include shrub swamp habitat in this part of Massachusetts. Long-term monitoring of occupied sites is necessary to evaluate the use of this habitat type over time. Because New England Cottontail and Eastern Cottontail are indistinguishable in the wild, documenting occurrences of New England Cottontail involves intensive effort. It requires that DNA be extracted from tissue taken from trapped rabbits or fecal pellets collected in the winter off fresh snow (to reduce the chance that DNA has degraded). Long-term monitoring to assess abundance and occupancy rates as well as the effectiveness of conservation efforts will require repeat visits to managed and unmanaged sites. The decline in New England Cottontail corresponds with the expansion of Eastern Cottontail and competition between them is not well understood. Additional research to examine interactions between these species and response to habitat management is needed.

Surveys for the Pale Green Pinion moth in acidic shrub swamps in the southeastern part of the state need to be conducted, as this species is undersurveyed in Massachusetts.

Research into the natural history of plants, particularly One-flowered Pyrola and Swamp Lousewort, is needed.

Education and Outreach
Keeping the public knowledgeable about shrub swamp ecology and the importance of the wetland type to SGCN is prerequisite to raising awareness of conservation needs. Providing educational services and opportunities for hands-on experience are key ways to keep the public interested and active in wetland conservation. Together, those actions should help foster public support for wetlands research, regulatory protections, and conservation initiatives. Products, services, and opportunities may include shrub swamp publications, website development, technical support for school studies/programs, coordination of citizen science projects, public presentations, and inclusion of citizen scientists in the NHESP's biological survey and/or restoration work.

DFW can support the efforts of partners such as the Grassroots Wildlife Conservation, the Parker River Clean Water Association, and others to raise awareness about the plight of the Blanding's Turtle and to engage communities and volunteers in monitoring and conservation action.

Under our partnership with NRCS, DFW staff work to make direct contact with private landowners and hold public information meetings designed to encourage them to apply for Working Lands for Wildlife funding or Wetland Reserve Easements to manage or protect shrub swamp habitat for Bog Turtle as well as other SWAP species.

Harvest and Trade Management
See Law Enforcement and Law and Policy sections, below.

Land and Water Rights Acquisition and Protection
Protecting land in and around shrub swamps supporting populations of rare and uncommon animals was supported in part by the NHESP *BioMap2* project that prioritized coarse-filter areas statewide for potential land-protection efforts. However, additional work is needed to identify specific shrub swamps that rank especially high in their value to SGCN and should be actively pursued in land acquisition/protection efforts by conservation agencies and organizations. Some of the Data Collection and Analysis actions described above are designed to inform land protection.

Shrub swamp habitat impacted by prior farming or forestry activity on private land may be eligible for enrollment in a Natural Resources Conservation Service Wetland Reserve Easement. This program is often used in Massachusetts to protect abandoned cranberry bogs and restore hydrology. Wetland Reserve Easements can also be used to protect shrub swamps along a watercourse that connects two existing parcels of protected land.

Law Enforcement
Four environmental laws in Massachusetts, described in the paragraphs below, should continue to be enforced rigorously statewide.

The NHESP regulates environmental impacts to shrub swamps where they are known to function as habitat for SGCN listed as under MESA. Published delineations of "Priority Habitat" for those species define specific geographic areas where most types of proposed land, water, or vegetation alterations are required to be reviewed and approved in advance by the NHESP. The review process can involve adjustment of project plans to avoid or minimize impacts to shrub swamps and their associated MESA-listed SGCN, or require mitigation of impacts that are deemed unavoidable. The MESA also provides for criminal and civil penalties for any unauthorized "take" of MESA-listed SGCN.

Hunting regulations (321 CMR 3.05) prohibit disturbance, harassment, or other taking of SGCN associated with shrub swamps, such as Jefferson Salamander, Blue-spotted Salamander, Marbled Salamander, Northern Leopard Frog, Bog Turtle, Blanding's Turtle, and Spotted Turtle.

Legislation signed in August of 2010 (Ch. 202 of the Acts of 2010) brought significant changes to Massachusetts Recreation Vehicle Laws. Among the new provisions are penalties for illegal use. The following are examples of prohibited operation of ORVs: operating on trails or in state forests / parks not designated for ORV use, operating in a manner so as to harass or chase wildlife or domestic animals, and operating on a wetland such as a bog, marsh, or swamp so as to destroy or damage the wetland. The ability to enforce the Massachusetts Recreation Vehicle Laws in certain areas and issues with addressing ORV use across state boundaries remain challenging.

The NHESP provides technical support to conservation commissions and the Massachusetts Department of Environmental Protection regarding their implementation of state-listed rare species provisions of the Massachusetts Wetland Protection Act.

Law and Policy
Coordinate with Conservation Commissions and DEP, through the administration of the Wetlands Protection Act, to determine the feasibility of wetland restoration. Establish a program to ease the permitting burden on land managers with approved restoration plans would greatly facilitate needed wetland restoration projects.

The need to adopt new regulations and/or policies may arise as knowledge is gained about climate change, emerging infectious disease, animal trade, and other threats.

Planning
Develop detailed conservation and recovery plans for SGCN associated with shrub swamps. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Discovery of undocumented local populations of SGCN may be a conservation priority, depending on the species targeted by a conservation and recovery plan. Additional priorities may include identification of all discrete wetlands currently used by a given local population of SGCN (e.g., in a metapopulation of Marbled Salamander) and an evaluation of the relative importance of each wetland to the population. Biological survey continues to be a cornerstone of the conservation strategy for shrub swamp SGCN, as the data generated are invaluable to informing other types of conservation actions. Identification and prioritization of prospective survey sites is an essential planning activity to maximize survey efficacy.

As one conservation strategy for species listed as Endangered, Threatened, or Special Concern pursuant to the MESA, the NHESP delineates "Priority Habitat" as a screening tool to regulate certain projects involving habitat alterations (see Law Enforcement above). Priority Habitat maps are distributed to the public and updated periodically to reflect new information about the occurrences of state-listed rare species, but the magnitude of changes in the maps from one cycle to the next can create a number of challenges that reduce the efficacy of the strategy. This problem is applicable to several shrub swamp SGCN, and there is a need to develop strategies for increasing the long-term stability of delineated habitat footprints. At minimum, the process will need to account for long-range population objectives and biological-inventory demands, and it will need to complement other conservation strategies effectively. Our approach to increasing stability of the regulatory footprint provides an exciting opportunity to forge a closer connection between regulation and proactive conservation planning and implementation.

Continue to participate in regional prioritization and conservation planning for Blanding's Turtle populations. Work with partners to develop and implement site-specific management plans for the highest-priority Blanding's Turtle populations in Massachusetts.

MassWildlife is a partner in the Rangewide New England Cottontail Initiative with the U.S. Fish and Wildlife Service, other state agencies, the Wildlife Management Institute, and the Natural Resources Conservation Service. Under this partnership, the *Conservation Strategy for the New England Cottontail* was produced, incorporating an adaptive approach designed to ameliorate threats to New England Cottontail through 2030. This partnership should continue and adapt to emerging issues in New England Cottontail conservation.

Species Reintroduction and Stocking
Translocation of SGCN to new sites or to sites of historical occurrence is a developing conservation strategy in Massachusetts; current projects involve Blanding's Turtle and Eastern Spadefoot. Likewise, augmentation of existing populations through captive rearing or "head-starting" of individuals for later release into those populations is an established, ongoing activity (e.g., Blanding's Turtle, Red-bellied Cooter). Reintroduction and stocking may grow as a conservation tool and involve additional SGCN, including some associated with shrub swamps. The approach could prove to be an effective way to reestablish local populations where only the organisms have been lost, but the habitat remains, as might occur with episodic disease outbreaks. This strategy has yet to be attempted with any of the plant SGCN known to occur in shrub swamps, but should be considered in areas where there is appropriate habitat and demonstrated ability to manage over the long term.

Consider the expanded use of headstarting to decrease the local extinction risk for isolated Blanding's Turtle populations (http://www.grassrootswildlife.org/projects.php).

The Conservation Strategy for the New England Cottontail includes a captive breeding program. Since 2010, captive breeding specialists at Roger Williams Park Zoo in Providence, Rhode Island, have been working to perfect housing, feeding, and breeding techniques so that New England Cottontails can be bred in captivity. Efforts are aimed at releasing captive-bred rabbits to the wild, both to boost the numbers and genetic diversity of existing populations and to start new populations on lands where rabbit habitat is being managed. This effort recently expanded to include captive breeding at the Bronx Zoo in New York, to which Massachusetts trapped and contributed founder rabbits. This effort should continue and be periodically evaluated for its efficacy.

Links to Additional Information

- Working Together for the New England Cottontail
- USDA-NRCS Working Lands for Wildlife

Forested Swamps

Habitat Description

Forested swamps are wetlands where trees dominate the vegetation. Soils are saturated for much of the growing season, often with standing water in the spring. Forested swamps are the most abundant types of all wetlands in the northeastern United States (Golet et al. 1993). They usually occur as patches or large patches within the surrounding upland matrix forest. They follow patterns of differences similar to the upland forests: In the northern hardwood zone of western and north-central Massachusetts, forested swamps are cold and often conifer-dominated. In the warmer southern and eastern sections of the state and in the central hardwood area, forested swamps are dominated by Red Maple or Atlantic White Cedar. See Figure 4-6, Massachusetts Ecological Provinces, in the Upland Forest section, above. As habitat, swamps are strongly affected by the type of tree, evergreen or deciduous, that forms the canopy.

From the mountainous northwestern part of the state at fairly high elevations, to sites near sea level along the coast, forested swamps include a wide variety of forest types and conditions. They occur in stream headwaters, behind floodplain forests, and in poorly drained basins. Spruce-fir Boreal Swamps, Hemlock Hardwood Swamps, and Atlantic White Cedar Swamps are coniferous, thus dark and acidic with year-round cover. Red Maple Swamps are the most common forested wetlands in Massachusetts. Red Maples (*Acer rubrum*) often occur with other hardwood tree species in particular situations. Calcareous Seepage Swamps are among the least common types of forested wetlands, and are rare natural communities in Massachusetts.

Evergreen swamps and deciduous swamps provide quite different habitats, both in the tree canopy and on the ground. Evergreen trees provide year-round cover, offering protective habitat for animals in the winter. They often have a less dense shrub layer than deciduous forested swamp. They also tend to be more acidic and have fewer amphibians in them than deciduous swamps.

Forested swamps develop in poorly drained areas throughout the state. Depending on the physical setting, forested swamps receive water through surface runoff, groundwater inputs, or stream and lake overflow. The hydrogeologic setting is the primary determinant of water regime and the plant community structure and composition, and so of animal habitat. Although some swamps are on mineral soils, most have some amount of muck, which are shallow to thick organic layers, overlying mineral sands, silts, or even bedrock. Peat accumulation is minimal at most sites for most types of forested swamps, but some accumulation does occur. Many occurrences of forested swamps have some groundwater seepage at their edges, which increases species and habitat diversity.

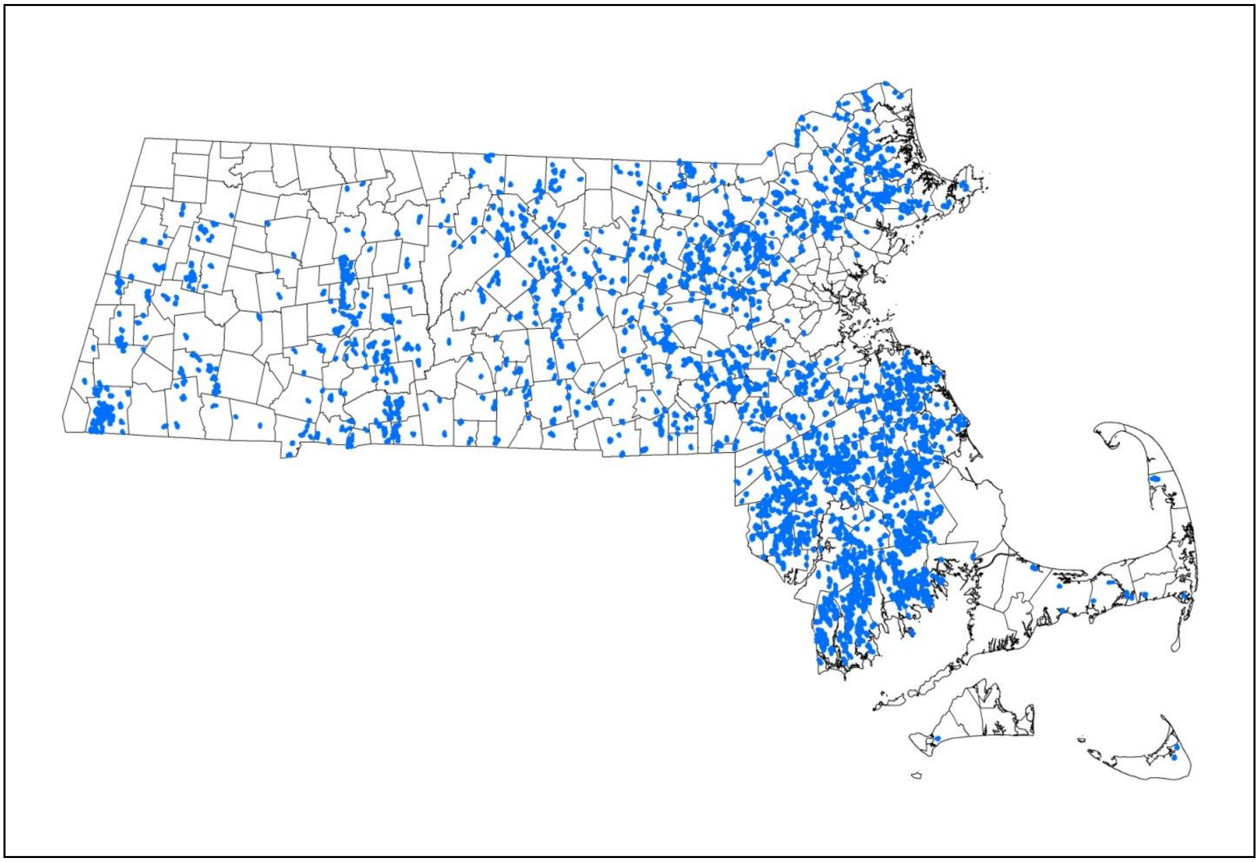


Figure 4-24: Larger Forested Swamps (25 acres or more) in Massachusetts.

These were derived from the MassGIS DEP Wetlands layer, and include Wooded Swamps–Coniferous, Wooded Swamps–Deciduous, and Wooded Swamps–Mixed.

Species of Greatest Conservation Need in Forested Swamps

Forty-two SGCN are assigned to the Forested Swamp habitat (Table 4-19).

Forested swamps function as breeding, foraging, and/or stopover habitat for a variety of amphibians in Massachusetts, including SGCN (Blue-spotted Salamander, Marbled Salamander) and common species (e.g., Spotted Salamander, Spring Peeper, Gray Treefrog, Wood Frog, Pickerel Frog, Green Frog). Portions of swamps that are characterized by 2-3 months of standing water during spring and an absence of predatory fish often function as vernal-pool habitat. Red Maple Swamps and Atlantic White Cedar Swamps appear to be especially important to Massachusetts populations of Marbled Salamander and Blue-spotted Salamander, respectively.

All ages of Spotted Turtles use all types of wetlands, including forested swamps, for overwintering, nesting, feeding, shelter, and aestivating (Fowle 2001). Eastern Ribbonsnake primarily eats fish and amphibians, and is often in or near vegetative cover at the edges of open water. A shrub layer is important part of their habitat because they climb into low vegetation, but seldom into the tree canopy (NatureServe 2005). They make use of a matrix of habitats and hibernate in uplands.

The American Black Duck can still be found nesting in shallow, nutrient-rich forested wetlands in Massachusetts, but they have become increasingly uncommon, largely a result of competition and hybridization with the Mallard (Walsh and Petersen 2013).

Songbirds (passerine species) of swamp forest are similar to the birds of structurally similar upland forests, but the dense shrub layers of many deciduous swamps provide excellent nesting locations for birds of thickets. For example, the Canada Warbler, a species of substantial conservation concern, is often found breeding in Red Maple swamps (Reitsma et al. 2010). One species of bird that specializes in forested swamps is the Northern Waterthrush. The state-rare Northern Parula nests only where there is abundant beard moss (*Usnea* lichen), which in Massachusetts has historically restricted it to a few Atlantic White Cedar swamps. However, there is recent evidence that this species is expanding its range in the western portion of the state (Walsh and Petersen 2013).

Many bird species use swamps extensively during migration or for wintering (Golet et al. 1993). Most notably, the rapidly declining Rusty Blackbird (Greenberg and Droege 1999) extensively uses forested swamps during migration, as they stop over to gain critical fat reserves to power their next migratory flight.

Many wide-ranging mammal species use swamp forests as part of their habitats. Bears use wetlands throughout the spring and early summer, especially when most food is unavailable but Skunk Cabbage has emerged. Some fruits, such as Highbush Blueberries, are eaten when they appear in the summer as a seasonal part of the diet. Other fruits and seeds, such as Winterberry, provide food through the winter. Shrubs may be browsed when the ground is frozen and they are most accessible, with more easily accessed upland browse used in the wetter seasons.

The amount of escape cover and water availability makes swamps important habitat for many species of small mammals (Golet et al. 1993). Survey work for New England Cottontail conducted in the last decade has resulted in documentation of this species in Forested Swamp habitat in winter. The dense shrub component of deciduous forested swamps provides significant cover essential to them, as they suffer very high natural predation. The amount of water within one kilometer of an occupied habitat patch has been linked to higher survival (Brown and Litvaitis 1995). The abundance of woody browse at ground level is also very important for cottontails in winter.

Rare butterfly and moth species that occur in forested swamps are found in particular types of forested swamps, not in all the variants. Hessel’s Hairstreak is a butterfly whose larvae feed exclusively on Atlantic White Cedar (*Chamaecyparis thyoides*). Therefore, this species is only found in Atlantic White Cedar swamps, and is largely restricted to southeastern Massachusetts, where most of these swamps occur. Similarly, larvae of the Bog Elfin feed exclusively on Black Spruce (*Picea mariana*), and this butterfly is found only in Black

Spruce swamps and bogs in the north-central part of the state. In Massachusetts, the Endangered Precious Underwing moth is found in only three acidic swamp habitats in the southeastern part of the state; larvae of this species feed on chokeberries (*Aronia* spp.). The Pale Green Pinion moth is also found in acidic swamps in the southeastern part of the state, typically deciduous swamps. Last but not least, the Threatened Mustard White butterfly is restricted to Berkshire County, where it is found in a variety of habitats, including deciduous swamps with mustard-family plants, upon which the larvae feed.

Several of the plant SGCN are known only from the calcareous wetlands and seepages, including Purple Cress, Chestnut-colored Sedge, Handsome Sedge, Yellow Lady's-slipper, Showy Lady's-slipper, White Adder's Mouth, Sweet Coltsfoot, Pink Pyrola, Bur Oak, and Arborvitae. Many of these are species of concern as Massachusetts does not have large areas of calcareous soil or bedrock. Some plants are at the southern edges of their range, such as Sweet Coltsfoot, Arborvitae, Sweet Bay, and Pink Pyrola, while Great Laurel is near its northern extent. Climbing Fern historically was quite common in the forested swamps of the Commonwealth, but was heavily collected and is now infrequent. Collection is probably a major reason that Showy Lady's-slipper has declined as well. Many orchids have been undergoing a decline, including the *Malaxis* and *Platanthera* species on the list associated with this habitat.

Table 4-19: Species of Greatest Conservation Need in Forested Swamps

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Clemmys guttata*	Spotted Turtle
	Thamnophis sauritus	Eastern Ribbonsnake
Birds	*Anas rubripes*	American Black Duck
	Buteo platypterus	Broad-Winged Hawk
	Cardellina canadensis	Canada Warbler
	Euphagus carolinus	Rusty Blackbird
	Setophaga americana	Northern Parula
	Zonotrichia albicollis	White-throated Sparrow
Mammals	*Sorex palustris*	Water Shrew
	Sylvilagus transitionalis	New England Cottontail
Crustaceans	*Synurella chamberlaini*	Coastal Swamp Amphipod
Lepidoptera	*Callophrys hesseli*	Hessel's Hairstreak
	Callophrys lanoraieensis	Bog Elfin
	Catocala pretiosa pretiosa	Precious Underwing
	Lithophane viridipallens	Pale Green Pinion
	Pieris oleracea	Mustard White
Plants	*Botrychium tenebrosum*	Swamp Moonwort
	Cardamine douglassii	Purple Cress
	Carex baileyi	Bailey's Sedge
	Carex castanea	Chestnut-colored Sedge
	Carex formosa	Handsome Sedge
	Cypripedium parviflorum	Yellow Lady's-slipper
	Cypripedium reginae	Showy Lady's-slipper
	Linnaea borealis ssp. *americana*	American Twinflower
	Lycopus rubellus	Taper-leaf Water-horehound
	Lygodium palmatum	Climbing Fern
	Magnolia virginiana	Sweet Bay
	Malaxis monophyllos var. *brachypoda*	White Adder's Mouth
	Malaxis unifolia	Green Adder's Mouth
	Moneses uniflora	One-flowered Pyrola
	Neottia bifolia	Southern Twayblade
	Orthilia secunda	One-sided Pyrola
	Petasites frigidus var. *palmatus*	Sweet Coltsfoot

Taxon Grouping	Scientific Name	Common Name
	Platanthera aquilonis	North Wind Orchid
	Platanthera macrophylla	Large Round-leaved Orchid
	Platanthera orbiculata	Round-leaved Orchid
	Populus heterophylla	Swamp Cottonwood
	Pyrola asarifolia ssp. *asarifolia*	Pink Pyrola
	Quercus macrocarpa	Bur Oak
	Rhododendron maximum	Great Laurel
	Rumex verticillatus	Swamp Dock
	Sanicula canadensis	Canadian Sanicle
	Thuja occidentalis	Arborvitae

Threats to Forested Swamps

IUCN Threat 1: Residential and Commercial Development
Development pressure in Massachusetts is high. Relatively strong environmental regulations in the state (e.g., Massachusetts Wetlands Protection Act) are effective in safeguarding most forested swamps from physical loss to residential and commercial development. However, portions of swamps that are small or otherwise inconspicuous are vulnerable to being overlooked, and terrestrial habitats surrounding forested swamps have few legal protections outside of the MESA legislation.

Land development that involves clearing, grading, filling, and/or building-construction and associated landscaping may result in the direct filling and permanent physical loss of forested swamp habitat. Increased impervious surface in the watershed, particularly in areas adjacent to a basin, may result in altered hydrologic function, reduced water quality, increased nutrient loading and sedimentation, increased salinization, and/or changes in surface water temperatures (Snodgrass et al. 2008). Amphibian SGCN, such as Blue-spotted Salamander and Marbled Salamander, that breed in forested swamps also require the terrestrial habitats surrounding the swamps to complete their life cycles. Hence, the breeding-habitat function of forested swamps can be indirectly disrupted when residential and commercial developments destroy associated terrestrial habitats (Homan et al. 2004). Losses or reductions of amphibian populations from those habitats can have impacts elsewhere in the food web (for example, egg masses of Spotted Salamander and Wood Frog are important food items for Spotted Turtle). When development occurs in the immediate vicinity of forested swamps and/or creates physical barriers between them, the ability of organisms (e.g., amphibians and reptiles) to access and populate those swamps is impaired, thus affecting the habitat function of the swamps and the metapopulation dynamics of associated SGCN. Development and associated traffic can also lead to direct mortality of amphibians and reptiles (Andrews et al. 2008), which is especially concerning for SGCN whose reproductive strategies are based on high annual adult survivorship – turtles in particular.

Changes in water quality and quantity threaten all wetlands. Changes in chemistry will alter herbaceous and eventually tree species, changing habitat for birds and browsers such as deer and rabbits, as well as invertebrates that depend on specific vegetation. Conversion to agriculture, filling for development and highway construction, and upland development adjacent to swamps all impact normal hydrology and geochemistry, and reduce the total acreage of swampland in the state. Alterations of water chemistry from road and farm runoff—in particular the accumulation of road salts—are additional threats to forested swamps.

Twinflower, One-flowered Pyrola, Swamp Dock, Sweet Coltsfoot, White Adder's Mouth and Southern Twayblade all seem to be particularly sensitive to development near them.

IUCN Threat 2: Agriculture and Aquaculture
Agricultural development pressure in most parts of Massachusetts is relatively low, and demand for "green" (especially organic) products from existing operations is relatively high. However, certain types of agricultural activities are exempt from most

environmental regulations in Massachusetts, including the Wetlands Protection Act. The limited exemptions are sometimes perceived by landowners as unlimited, "blanket" exemptions, and so unlawful loss of forested swamps (or portions of forested swamps) to agricultural development does occur on occasion.

Agricultural development involving clearing, grading, and/or filling may result in the direct filling and permanent physical loss of forested swamp habitat. Maintenance or improvement of agricultural lands may include ditching and draining of forested swamps whose surface waters spill onto fields during annual spring floods. Agricultural dumping may physically and/or chemically alter portions of forested swamps. Runoff from agricultural fields may negatively alter soil and water chemistry and, therefore, harm associated amphibians via introduction of fertilizers, pesticides, and/or herbicides (Rouse et al. 1999; Burgett et al. 2007; Baker et al. 2013).

IUCN Threat 3: Energy Production and Mining
Energy production and mining pressure in Massachusetts is probably considered moderate. Despite relatively strong environmental regulations in the state, energy production is a high-ranking public need, and some long-established sand/gravel mining operations are not always subject to more recently established regulations and/or permitting requirements. Energy production, such as solar arrays, wind turbines, and plants of various types, and sand/gravel mining tend to be relatively localized threats, but they can be significant to swamp ecology where they occur, based on a number of variables (e.g., size of project, size and configuration of swamp habitat and biologically important portions thereof). Terrestrial habitats surrounding forested swamps are highly vulnerable, as there are few legal protections for those areas besides the MESA.

Energy production and/or mining activities that involve clearing, blasting, grading, and/or filling may result in the direct filling and permanent physical loss of forested swamp habitat. Amphibian SGCN such as Blue-spotted Salamander and Marbled Salamander that breed in forested swamps also require the terrestrial habitats surrounding the swamps to complete their life cycles. Hence, the breeding-habitat function of forested swamps can be indirectly disrupted when large-scale energy production and/or mining activities destroy the associated terrestrial habitats. Losses or reductions of amphibian populations from those habitats can have impacts elsewhere in the food web (for example, egg masses of Spotted Salamander and Wood Frog are important food items for Spotted Turtle). When energy production and/or mining activities occur in the immediate vicinity of forested swamps and/or create physical barriers between them, the ability of organisms (e.g., amphibians and reptiles) to access and populate those swamps is impaired, thus affecting the habitat function of the swamps and the metapopulation dynamics of associated SGCN.

IUCN Threat 4: Transportation and Service Corridors
Forested swamps receive some regulatory protection via the Massachusetts Wetlands Protection Act from direct loss to development of new transportation and service corridors. However, terrestrial habitats surrounding swamps are quite vulnerable, as there are few legal protections for those areas besides the MESA. There are few to no regulatory protections for forested swamps with respect to pollution from road/highway runoff, or with respect to the alteration of swamp ecology caused by road-related animal mortality and habitat fragmentation.

Density of transportation and service corridors in Massachusetts is relatively high, and so the threat of development of new corridors is relatively low in most parts of the state. However, several proposed corridors may be highly ranked public needs, and portions of some forested swamps may ultimately be lost as a result of their development. Pollution associated with road/highway runoff is a continuing concern for many swamps, and mortality of dependent organisms attempting to cross roads is considered a major threat to swamp ecology throughout much of the state.

Invasive plant species use both transportation and utility-service corridors as a launching point into forested swamps. Intact forested-swamp canopies provide sufficient shade that invasive plants are slowed in their growth; openings in the canopy associated with roads and service corridors allow invasive plant species to spread along the openings. Specific plants that might invade forested wetlands are discussed in more detail in IUCN Threat 8.

Existing transportation and service corridors (roads, highways, railways) often act as physical barriers to movement and/or are sources of adult mortality for organisms (salamanders, frogs, turtles) that use forested swamps and must traverse terrestrial habitat to access them (Gibbs 1998; Gibbs and Shriver 2005;

Andrews et al. 2008; Bartoszek and Greenwald 2009; Sutherland et al. 2010). Roads/highways with high traffic volume also create noise pollution, which may alter breeding behavior (such as frog calling) in nearby wetlands in ways that either impair breeding activity (Tennessen et al. 2014) or result in certain tradeoffs that could conceivably reduce reproductive fitness (Parris et al. 2009; Cunnington and Fahrig 2010). In addition, transportation corridors are sources of chemical pollution for many swamps in Massachusetts, as storm runoff from roads and highways introduces metals, salts, oils, and other compounds, thus altering wetland chemistry and, in some cases, impairing or destroying the biological function of the habitat (Turtle 2000; Croteau et al. 2008; Karraker et al. 2008; Brady 2012). Hence, existing transportation/service infrastructure may indirectly impact forested swamp habitat by limiting or reducing local biodiversity (Fahrig and Rytwinski 2009). Roadsides, powerline corridors, and similar areas are also often corridors for the easy movement of terrestrial exotic invasive plants of ruderal habitats.

Road salt and its associated components, in particular chloride, has been increasing in these habitats from stormwater runoff. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into associated wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations to plants and animals.

Development of new transportation and service corridors involves clearing, grading, and/or filling, which can result in increased erosion and sedimentation, direct filling, and/or conversion of forested swamp habitat to shrub swamp or marsh habitat. Regardless, development of new corridors through forested swamps results in some permanent physical loss of the habitat. Development of new corridors through forested swamps may also alter the hydrological regime of the wetland, or portions thereof.

In Massachusetts, analysis of 272 road-killed-rabbit carcasses collected between 2009 and 2013 from locations where New England Cottontail and the introduced Eastern Cottontail both occur resulted in only 18 New England Cottontail mortalities, while 247 were Eastern Cottontails. It is unknown if New England Cottontail avoid crossing roads to forage in or disperse to suitable habitat. Utility corridors including powerlines and pipelines may serve to facilitate dispersal of New England Cottontail from forested swamp habitat to other suitable areas.

IUCN Threat 5: Biological Resource Use

Some SGCN (such as Spotted Turtle) associated with forested swamps are poached for trade or other illegal uses, and the risk of ad hoc collecting facilitated by chance encounters with turtles likely increases as habitat fragmentation and human population density increase. However, the magnitude of the problem in Massachusetts is unknown.

Timber harvesting (logging) is a common land use in most parts of Massachusetts (except for Cape Cod). Logging can impact forested-swamp ecology in a number of ways, not all of which are well understood (deMaynadier and Houlahan 2008). Logging removes portions of the forest canopy and therefore alters light conditions, water temperature, organic inputs, and nutrient cycling in and around wetlands. Logging also compacts and/or ruts soils and may introduce nonnative invasive plants to the swamp and surrounding terrestrial habitat. Establishment of logging roads/trails adjacent to or through swamp basins can create problems with erosion and runoff, thus impacting water quality. Logging may be considered a minor to moderate threat to forested swamps in Massachusetts. Other than the problem of nonnative invasive plants, logging-associated impacts to forested swamps often tend to be minor, temporary, and/or minimized by regulatory protections (e.g., the Forest Cutting Practices Act regulations [304 CMR 11.00]). However, removal of forest canopy and operation of heavy equipment are allowed within forested swamps, and so alterations of the habitat do occur with regularity. Ruts from the logging roads can change the microhydrology of sites, which might impact plant SGCN in these areas.

Intense logging will drastically change the forested swamp habitat. There are times when less intense logging might be necessary to reestablish particular forest types, such as Atlantic White Cedar, where partial cuts allow competitors like Red Maple to replace the cedar. Additionally, harvesting of some trees within a forested swamp can result in an increase in regrowth of woody understory vegetation that provides food and cover for small mammals such as cottontail rabbits.

IUCN Threat 6: Human Intrusions and Disturbance
An unknown amount of forested swamp habitat in Massachusetts is impacted by human intrusions and disturbance. The most commonly observed disturbances are dumping and intentional filling. Generally, smaller swamps or the margins of larger swamps are most vulnerable.

Dumping activity, as evidenced by the types of old cars and household appliances found in swamps, appears to be less substantial now than in decades past. However, dumping of trash, tires, brush, and lawn clippings is an ongoing threat to forested swamps located near roadside pull-offs, trailheads, and suburban yards. Intentional filling with tree limbs, leaves, and other yard waste by landowners attempting to manage surface water on or adjacent to their properties is an occasional problem. The degree to which dumping and filling impact forested swamps varies by locality, but smaller basins in areas of greater human population density tend to be most at risk. Most forested swamps are legally protected from dumping/filling, but detection of violations and/or identification of violators can be difficult.

Humans may be attracted to enter forested swamps to collect some of the larger orchids, threatening their continued populations in these locations.

IUCN Threat 7: Natural System Modifications
A main threat to forested swamps is alteration of the hydrological regime. Changes in either surface water or groundwater alter the flooding regime and the minerals and nutrients carried to the swamps, and can change the wetland status and the species involved. Many of the rare plant species associated with this habitat are threatened by changes in the hydrologic regime.

Abstraction of ground water and surface water from streams or ponds for residential, commercial, and agricultural uses could potentially threaten forested swamps in Massachusetts. Substantial abstractions within the watershed during droughty conditions for residential and agricultural irrigation or commercial snow production could contribute to low water tables and, therefore, shorten periods of inundation and soil saturation in area swamps. This threat is under-investigated in Massachusetts, and so its magnitude is unknown.

Forested swamps are vulnerable to dramatic alterations by beaver activity. As beaver dams are created and grow in size, substantial impoundments of water are created, thereby establishing a permanent hydroperiod, engulfing understory vegetation, and killing overstory trees. Hence, portions of forested swamps that previously functioned as vernal pool habitat are severely impaired for some SGCN (e.g., Marbled Salamander). After beavers abandon an impoundment and dams are breached, the habitat may eventually revert back to forested swamp. However, the cycle of beaver occupation, abandonment, draining, forest regrowth, and wetland recolonization by the original suite of swamp organisms can be lengthy, playing out over many decades. In habitat patches isolated by roads and development, such temporary loss of forested swamp habitat can have permanent impacts on local populations of organisms. Beavers are common and widespread throughout most of Massachusetts, but the magnitude of their threat to forested swamp habitat is underinvestigated. Where topography is only slightly sloped, beaver activity may result only in a shift in the distribution of forested swamp habitat, or perhaps even result in a net gain of the habitat.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Water-level disturbance can lead to invasion by nonnative plants, including the aggressive exotics Purple Loosestrife (*Lythrum salicaria*), Tatarian Honeysuckle (*Lonicera tatarica*), Morrow's Honeysuckle (*L. morrowii*), Glossy Buckthorn (*Frangula alnus*) and Common Buckthorn (*Rhamnus cathartica*). Common Reed (*Phragmites australis*) is also an aggressive exotic in disturbed forested swamps.

For some of the plants, hybridization is a concern, including Purple Cress, which hybridizes with other *Cardamine* spp., and Bur Oak, which hybridizes with other white-oak species, in particular Swamp White Oak. Swamp Cottonwood in Massachusetts may be one clone, which has limited ability to reproduce other than vegetatively.

Interactions between the introduced Eastern Cottontail and New England Cottontail are not well known or understood. These species are sympatric and competition for resources would be expected. Preliminary research indicated some segregation of co-occupied habitat patches. There has been no evidence of interbreeding; however, failed attempts to breed may negatively impact reproductive rates of New England Cottontail.

Particular tree and shrub species can be preferentially selected by deer for browsing, with a resulting change in composition and structure of vegetation when deer populations are high. Heavy browsing by deer has been shown to prevent reproduction of cedar trees and chokeberry shrubs after fires and logging (NatureServe, 2005), which is particularly detrimental to Hessel's Hairstreak and the Precious Underwing, respectively. Deer browse heavily on Showy Lady's-slipper, Yellow Lady's-slipper, Sweet Bay, and Bur Oak.

Emerging infectious disease is currently considered one of the greatest threats to global biodiversity, and amphibians are an especially vulnerable group. Although amphibians in the New England region appear to be relatively resistant to some pathogens that are problematic elsewhere in the world (e.g., the chytrid fungus *Batrachochytrium dendrobatidis* [*Bd*]; Longcore et al. 2007; Richards-Hrdlicka et al. 2013), there is suspicion that other pathogens such as ranavirus have caused recent mass-mortality events in vernal pools of the region (Wheelright et al. 2014), including Massachusetts. Since many forested swamps (or portions of swamps) function as vernal pool habitat for amphibian SGCN and are used by other amphibian and reptile species known to be carriers of ranavirus, forested-swamp ecology is vulnerable to impacts of the spread of emerging infectious disease. Of particularly grave concern is the potential for future introduction and spread of the salamander fungus *Batrachochytrium salamandrivorans* (*Bsal*), known best for its devastating impacts on amphibians in Europe (Martel et al. 2014).

The potential spread of pathogens among forested swamps may be facilitated by animal commerce, illegal animal translocations, use of contaminated field gear during biological surveys, and natural dispersal of native fauna (Picco and Collins 2008; Gray et al. 2009). Infection rates and long-term impacts to forested swamps and their associated organisms are understudied in Massachusetts. However, ranavirus is known to affect or be carried by a wide variety of taxa (frogs, salamanders, turtles, fish), and research findings in other parts of the country suggest that it can have severe and acute impacts on amphibians (Gray et al. 2009; USGS 2012; Brenes et al. 2014; Currylow et al. 2014). Given great difficulty in controlling the spread of pathogens, and the lack of knowledge about persistence and long-term consequences of local outbreaks, emerging infectious disease must be considered a major threat to forested-swamp ecology in Massachusetts. Relatively small swamps are likely the most vulnerable.

IUCN Threat 9: Pollution

Mercury released into the air (e.g., from coal-burning power plants) can spread across the globe and falls to the ground through atmospheric deposition. Bacteria found in wet areas transform mercury into methylmercury, which allows it to enter the food chain. Organisms that are higher on the food chain are generally more vulnerable to mercury contamination due to bioaccumulation of the element. Mercury contamination may be contributing to the mysterious decline of the Rusty Blackbird (Evers et al. 2012).

Forested swamps are vulnerable to nutrient loading and/or chemical contamination when they are adjacent to lawns, golf courses, crop fields, parking lots, roads, gas stations, and other areas where accidental spills or deliberate applications of chemicals occur (Snodgrass et al. 2008). Surface runoff from those areas can introduce contaminants to swamps, thus altering water chemistry and impairing biological function (Burgett et al. 2007; Croteau et al. 2008; Baker et al. 2013). Of particular concern is the threat of road deicing salts to amphibian reproduction (Turtle 2000; Karraker et al. 2008; Karraker and Gibbs 2011; Brady 2012). Forested swamps are typically afforded 100-foot terrestrial buffers via the Massachusetts Wetlands Protection Act to mitigate the threat of contamination by runoff, but those regulatory protections do not apply to land uses that were in place prior to enactment of the legislation. Given the high human population density in Massachusetts, many shrub swamps are impacted by contamination via surface runoff.

Acidification of forested swamps may be a concern where they function as breeding habitat for amphibians. Low pH (e.g., less than 4.5) can inhibit embryonic and larval development and survival, thereby reducing reproduction and recruitment (Freda and Taylor 1992; Karns 1992; Sadinski and Dunson 1992). Increases in acid precipitation may alter water chemistry in smaller swamps slowly over time, or particularly heavy precipitation events may trigger sudden spikes in aluminum, which is toxic to larval amphibians (Jackson and Griffin 1991; Horne and Dunson 1995; Croteau et al. 2008).

IUCN Threat 10: Geological Events
Geological events are not a major threat the forested swamps in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Climate change analyses project varying scenarios for the northeastern United States. Although total precipitation is expected to increase, other common predictions include warmer temperatures, longer and more severe summer droughts, shorter but more intense winter/spring floods, and reduced extent and duration of winter snow cover. Taken together, such changes could alter the hydrological regimes of many forested swamps in the region. Expected outcomes include seasonal drying of wetland soils when water tables drop during extended droughts, which could facilitate changes in dominant vegetation. Conceivably, smaller forested swamps could be lost entirely, while larger ones could contract in area or become fragmented.

Assuming increased frequency and duration of summer droughts in the region, some reduction in the availability of forested swamp habitat may affect amphibian SGCN to different degrees. Atlantic White Cedar Swamps are relatively uncommon in Massachusetts, and one such swamp appears to support one of the most important populations of Blue-spotted Salamander in all of New England. Contraction, fragmentation, or alteration of the hydrological regime of that particular habitat would be of major concern. Conversely, Red Maple swamps are common and widespread in Massachusetts, and so a slight to modest reduction of that type of forested swamp would be expected to have less of an impact to associated amphibian SGCN, such as Marbled Salamander.

Climate change was addressed in the *Conservation Strategy for the New England Cottontail* and determined not to be considered a threat. In Massachusetts, severe winter weather was identified as a potential threat in southwestern parts of the species' range.

Both the Bog Elfin and the Mustard White butterflies are at the southern extent of their geographic ranges in Massachusetts; these species may retreat northward with climate warming, resulting in their extirpation from the state.

Climate change is predicted to consist of warmer temperatures and an increase in severe weather events. For forested wetlands, this is likely to result in a higher evapotranspiration rate as trees and herbaceous plants respond to the higher temperatures. Higher rates of evapotranspiration may cause a drawdown of the groundwater table, and may change the plant community structure. In contrast to the higher rates of evapotranspiration, climate change in Massachusetts is also predicted to result in higher precipitation rates, and in the past two decades, the groundwater table region-wide has increased to its highest levels over the past 500 years (Pederson et al. 2013, 2014; Newby et al. 2014; Weider and Boutt 2010).

Some habitats are likely to become wetter where there is higher groundwater input, while others may become drier. Species that thrive in the current conditions may no longer be able to survive. As mentioned above, several of the plant SGCN are at the southern edge of their range. Climate change may make their current sites in Massachusetts inhospitable. Although Great Laurel in near its northern extent, recent colonizations have not been observed.

Conservation Actions

Direct Management of Natural Resources
The Massachusetts Division of Fisheries & Wildlife developed Best Management Practices for controlling the spread of invasive species. This involves thoroughly cleaning the exterior, undercarriage, and tires/tracks of equipment being used for habitat management with a high-pressure washer prior to arriving on the property, to reduce the risk of invasives being carried onsite from other locations. Following these is required for contractors working on the Division's land and recommended for management projects taking place on private or other conserved land.

The Division works under a formal partnership with the USDA Natural Resources Conservation Service to plan habitat management projects on privately owned land aimed specifically at benefitting SWAP species, through Farm Bill Program funding assistance or Wetland Reserve Easements. Projects are funded through Farm Bill Programs. Management activities conducted in forested swamp habitat may include invasive-species control or partial tree-canopy removal to increase woody understory vegetation. This program should continue and be expanded.

Some of the rare plant species that grow in Forested Swamps are observed most frequently in openings in the forests. These populations should be monitored, and openings in the canopy should be maintained as needed for these species.

Data Collection and Analysis
Because New England Cottontail and Eastern Cottontail are indistinguishable in the wild, documenting the occurrences of New England Cottontail involves intensive effort. It requires that DNA be extracted from tissue taken from trapped rabbits or fecal pellets collected in the winter off fresh snow (to reduce the chance that DNA has degraded). Long-term monitoring to assess abundance and occupancy rates as well as the effectiveness of conservation efforts will require repeat visits to managed and unmanaged sites.

Habitat modeling for New England Cottontail indicates wetland complexes that include forested swamps have high suitability for the species, and survey work has been focused in these areas in the Southern Berkshires. In some locations, New England Cottontail has persisted for at least 10 years in unmanaged forested swamp habitat in this part of Massachusetts. Long-term monitoring of occupied sites is necessary to evaluate the use of this habitat type over time.

In locations where active management involves tree canopy removal to manipulate species composition such as promoting Atlantic White Cedar or increase understory woody vegetation for New England Cottontail, the effects on SWAP species need to be documented.

Analyze the results of planned forest harvests in forested swamps, to document effects on rare and uncommon species.

Locate large forested swamps statewide via aerial photo-interpretation, map them, and field-survey a selected percentage of these swamps for SWAP species. Biological inventory and monitoring of forested swamps are necessary to identify and understand distribution and abundance of associated SGCN. Data generated by such surveys are critical to establishing and maintaining site-specific regulatory protections for SGCN and to developing effective, long-term conservation plans for the species. Biological inventory data are needed to assess the basic population status of some SGCN, answer outstanding questions about population genetics, or even confirm suspected species identities (e.g., certain local populations of leopard frogs).

Conduct species-specific research at forested swamps to fill data gaps associated with SGCN life history, habitat requirements, population ecology, sampling techniques, and other topics. Forested swamps function as population centers for several SGCN and, therefore, are natural sites for studying fundamental aspects of the species and improving our knowledge about how to study them more effectively. Investigations into population genetics, microhabitat preferences, metapopulation dynamics, and survey efficacy are examples of research that will help inform conservation planning and associated actions. One priority is to work with conservation partners to improve our understanding of the genetic structure of salamander populations in the Jefferson/Blue-spotted salamander complex. Preliminary findings from an earlier NHESP study suggest that such work could play a major role in prioritizing sites for conservation (Charney et al. 2014).

Include a sample of forested swamps in a long-term, statewide monitoring program for vernal pool and other wetland habitats. Long-term monitoring of forested swamp hydrology, chemistry, pathogen loads, and associated SGCN demographics as part of a larger wetland monitoring program is needed to detect, understand, and act on SGCN population trends at both local and state scales. Such a program would be especially beneficial in understanding and planning for impacts associated with climate change, emerging infectious disease, pollution, and habitat loss/fragmentation. Comparing vulnerabilities of certain classifications of forested swamp versus "classic" vernal pools would provide useful information in assessing overall threats to certain SGCN that utilize multiple habitat types (e.g., Marbled Salamander).

Survey for Water Shrew and Coastal Swamp Amphipod to determine their range, abundance, and distribution in the state, as these species are undersurveyed in Massachusetts.

Education and Outreach
Produce and provide educational products, services, and opportunities to the Massachusetts public regarding forested swamp ecology and conservation. Keeping the public knowledgeable about forested swamp ecology and the importance of the wetland type to SGCN is prerequisite to raising awareness of conservation needs. Providing educational services and opportunities for hands-on experience are key ways to keep the public interested and active in wetland conservation. Together, those actions should help foster public support for wetlands research, regulatory protections, and conservation initiatives. Products, services, and opportunities may include forested swamp publications, website development, technical support for school studies/programs, coordination of citizen science projects, public presentations, and inclusion of citizen scientists in the NHESP's biological survey and/or restoration work.

Harvest and Trade Management
See Law Enforcement and Law and Policy below.

Land and Water Rights Acquisition and Protection
Develop and maintain a list of forested swamps that should be considered priorities in land protection for SGCN. The NHESP *BioMap2* project prioritized coarse-filter areas statewide for potential land protection efforts. However, additional work is needed to identify specific forested swamps that rank especially high in their value to SGCN and thus should be actively pursued in land acquisition/protection efforts. Some of the Data Collection and Analysis actions described above are designed to inform land protection.

Forested-swamp habitat impacted by prior farming or forestry activity may be eligible for enrollment in a Natural Resources Conservation Service Wetland Reserve Easement to protect the wetland and restore hydrology. Wetland Reserve Easements can also be used to protect forested swamps along a watercourse that connects two existing parcels of protected land.

Law Enforcement
Continue to implement legal mandates of the MESA (M.G.L. c. 131A) and regulations (321 CMR 10.00). The NHESP regulates environmental impacts to forested swamps where they are known to function as habitat for SGCN listed as Endangered, Threatened, or Special Concern pursuant to the MESA. Published delineations of Priority Habitat for those species define specific geographic areas where most types of proposed land, water, or vegetation alterations are required to be reviewed and approved in advance by the NHESP. The review process can involve adjustment of project plans to avoid or minimize impacts to forested swamps and their associated MESA-listed SGCN, or require mitigation of impacts that are deemed unavoidable. The MESA also provides for criminal and civil penalties for any unauthorized "take" of MESA-listed SGCN.

Enforce other laws that protect SGCN associated with forested swamps, such as the Massachusetts Wetlands Protection Act and the Forest Cutting Practices Act. Hunting regulations (321 CMR 3.05) prohibit disturbance, harassment, or other taking of SGCN associated with shrub swamps, such as Blue-spotted Salamander, Marbled Salamander, and Spotted Turtle.

Continue to provide technical support for implementation of other laws protecting forested swamps and associated SGCN. The NHESP provides technical support to conservation commissions and the Massachusetts Department of Environmental Protection regarding their implementation of state-listed rare-species provisions of the Massachusetts Wetland Protection Act.

Law and Policy
Develop or update regulations and policies as necessary to address emerging threats. Needs to adopt new regulations and/or policies may arise as

knowledge is gained about climate change, emerging infectious disease, animal trade, and other threats.

Planning

Develop detailed conservation and recovery plans for SGCN associated with forested swamps. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Develop and maintain lists of forested swamps that should be considered priorities in future biological surveys for SGCN. Discovery of undocumented local populations of SGCN is a conservation priority. Additional priorities include identification of all discrete wetlands currently used by a given local population of SGCN (e.g., in a metapopulation of Marbled Salamander) and an evaluation of the relative importance of each wetland to the population. Biological survey continues to be a cornerstone of the conservation strategy for forested swamp SGCN, as the data generated are invaluable to informing other types of conservation actions. Identification and prioritization of prospective survey sites is an essential planning activity to maximize survey efficacy.

Develop strategies for stabilizing Priority Habitat maps as they pertain to forested swamp SGCN. As one conservation strategy for species listed as Endangered, Threatened, or Special Concern pursuant to the MESA, the NHESP delineates Priority Habitat as a screening tool to regulate certain projects involving habitat alterations (see Law Enforcement above). Priority Habitat maps are updated periodically to reflect new information about the occurrences of state-listed rare species, but the magnitude of changes in the maps from one cycle to the next can create a number of challenges that reduce the efficacy of the strategy. This problem is applicable to several forested-swamp SGCN, and there is a need to develop strategies for increasing the long-term stability of delineated habitat footprints. At minimum, the process will need to account for long-range population objectives and biological inventory demands, and it will need to complement other conservation strategies effectively. Our approach to increasing stability of the regulatory footprint provides an exciting opportunity to forge a closer connection between regulation and proactive conservation planning and implementation.

Species Reintroduction and Stocking

The *Conservation Strategy for the New England Cottontail* includes a captive-breeding program. Since 2010, captive breeding specialists at the Roger Williams Park Zoo in Providence, Rhode Island, have been working to perfect housing, feeding, and breeding techniques so that New England Cottontails can be bred in captivity. Efforts are aimed at releasing captive-bred rabbits to the wild, both to boost the numbers and genetic diversity of existing populations and to start new populations on lands where rabbit habitat is being managed. This effort recently expanded to include captive breeding at the Bronx Zoo in New York, to which Massachusetts trapped and contributed founder rabbits.

Conduct species introduction/reintroduction/augmentation projects with forested swamps as release sites. Translocation of SGCN to new sites or to sites of historical occurrence is a developing conservation strategy in Massachusetts; current projects involve Blanding's Turtle and Eastern Spadefoot. Likewise, augmentation of existing populations through captive rearing or head-starting of individuals for later release into those populations is an established, ongoing activity (e.g., Blanding's Turtle, Red-bellied Cooter). Reintroduction and stocking may grow as a conservation tool and involve additional SGCN, conceivably including some associated with forested swamps. The approach could prove to be an effective way to reestablish local populations where only the organisms have been lost, but the habitat remains as might occur with episodic disease outbreaks. In areas where appropriate management can be assured, as on state-owned Wildlife Management Areas, introduction and reintroduction of listed plant species may be appropriate.

Links to Additional Information

- Working Together for the New England Cottontail - a partnership aimed at conserving the New England Cottontail

Lakes and Ponds

Habitat Description

Massachusetts contains nearly 3,000 named lakes and ponds, which, in sum, comprise over 150,000 surface acres of water. Many lakes and ponds, such as kettlehole ponds on the Cape, were formed naturally over 10,000 years ago during the retreat of the last ice age. However, numerous other waterbodies were created by humans in the 19th and early 20th centuries for small-scale power generation and municipal water consumption. Today, these waterbodies are important sources of water for many communities but also afford recreational opportunities such as boating, fishing, and swimming.

Most importantly, however, lake and pond environments function as key habitats for a wide variety of fish, wildlife, and plant species. Thus, maintaining the health of these habitats is paramount to the sustainability of these species over time.

Lake and pond environments in Massachusetts are typically small: 90% of the total statewide surface area of water comes from ponds that are less than 10 acres in size. These habitats are generally shallow and can warm appreciably during summer, which, in concert with other factors, can constrain the diversity of biotic communities in the ponds. Alternatively, larger, deeper waterbodies, such as the Quabbin and Wachusett reservoirs, while less common, are significant in that they retain cool, oxygenated water throughout the year capable of supporting more diverse fauna such as both cold- and warmwater fish species. All lake and ponds, regardless of size or depth, undergo a natural aging process by which they slowly accumulate nutrients (eutrophication), fill, and warm with concomitant changes to natural communities. Normally, this process occurs over thousands of years but can speed appreciably as a result of anthropogenic activity.

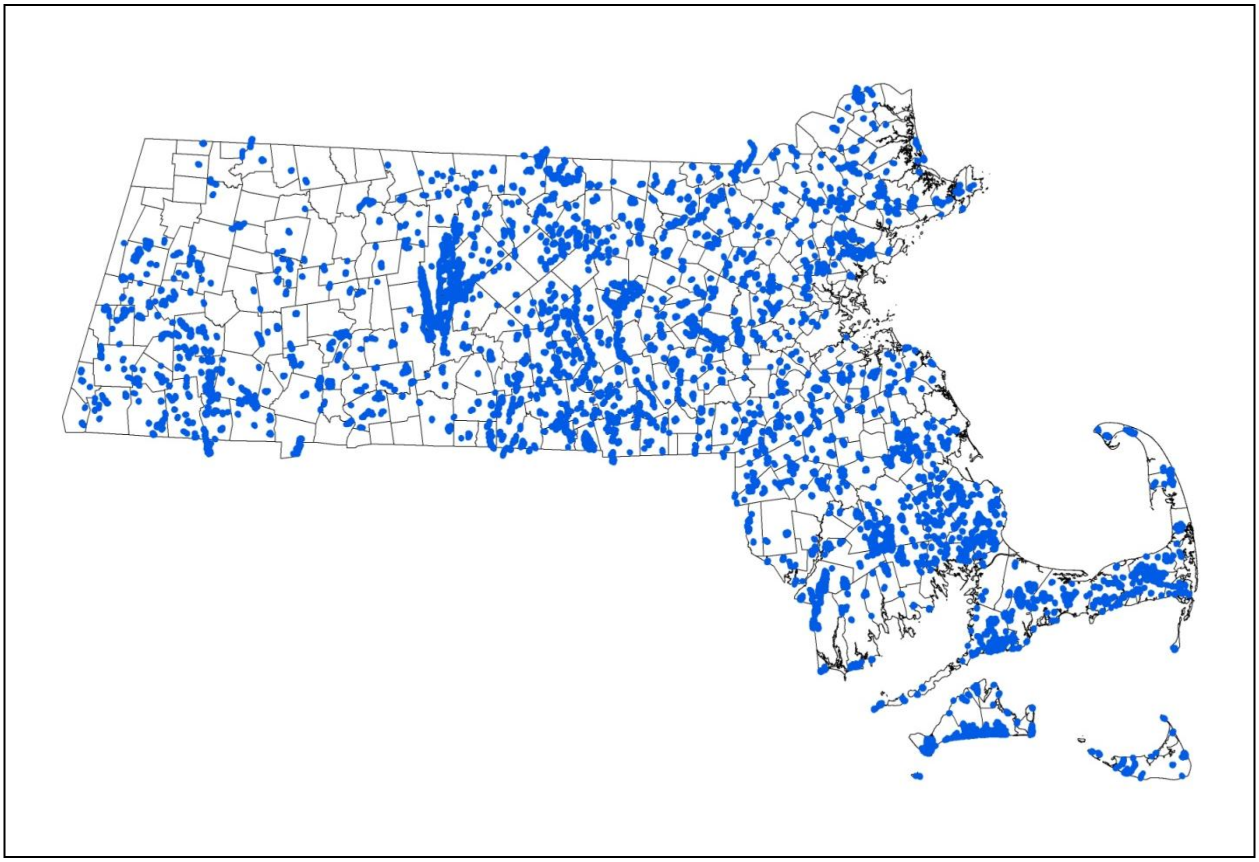


Figure 4-25: Larger Lakes and Ponds (10 acres or more) in Massachusetts.

Species of Greatest Conservation Need in Lakes and Ponds

Fifty-nine SGCN are assigned to the Lakes and Ponds habitat (Table 4-20).

Eight of the 28 fish species included in the list of SGCN inhabit lake and pond environments for at least a portion of their lifecycles, including two diadromous species. American Eel migrate to and spawn in the Sargasso Sea but the majority of their lives is spent in freshwater, including lakes and ponds. Alternatively, Alewives spend the majority of their lifetime in salt water, but migrate to freshwater habitats, including lakes and ponds, to spawn. For both species, connectivity to marine environments is critical for the successful completion of life cycles and largely restricts the distribution of these species in Massachusetts.

The remaining SWAP fish species are typically restricted to littoral habitats of lakes and ponds for the majority of the year. Littoral habitats are shallow areas of lake margins that lie within the photic zone, resulting in the presence, and often proliferation, of aquatic vegetation. This aquatic vegetation provides essential foraging, spawning, and refuge habitat for all life stages of these fish species. With the exception of Banded Sunfish and Swamp Darter, which are limited to eastern portions of the state, these fish can be found throughout Massachusetts, but often in low abundance. Landlocked Threespine Sticklebacks are known to be present in only one pond, in Olmstead Park, Boston.

One amphibian and two reptile species included in the SGCN list inhabit lake and pond environments. Northern Leopard Frog can be found in damp, heavily vegetated areas of lake margins or swampy areas, as well as adjacent terrestrial habitats, which provide foraging, refuge, and breeding habitats. Populations may be found statewide, with the exception of the Cape and Islands, but are often highly localized. Northern Red-bellied Cooter is a federally Threatened species that can be found in heavily vegetated areas of lakes and ponds in Plymouth and Bristol counties. Historically, these turtles were likely found in coastal areas from Massachusetts to North Carolina. Their current range extends only as far north as New Jersey with an isolated, disjunct population in Massachusetts. Eastern Ribbonsnakes are found in and around vegetated areas of lake margins and range throughout Massachusetts, often in low abundance.

Five SWAP bird species need lake and pond environments. American Black Duck are dabblers and feed on submerged aquatic vegetation in littoral habitats of lakes and ponds. These ducks can be found throughout the state but their numbers are thought to be in decline. Common Loons occur statewide as migrants, stopping over at some of the state's larger interior lakes and reservoirs; they breed on several of the largest lakes. Common Loons are diving ducks, foraging on small fish, and prefer large expanses of open-water habitat. Bald Eagles forage on moderate to large-sized fish and require unimpeded views (open water) to see and capture prey, as well as mature trees in which to nest. As a result, Bald Eagles are restricted to habitats in and around some of the state's larger inland waters and are found sporadically throughout the state. Pied-billed Grebes use vegetated littoral and shoreline habitats of lakes and large ponds in Massachusetts to breed and rear young during spring and summer. The population of Pied-billed Grebes in Massachusetts is thought to be small, with nesting often occurring erratically even at known breeding sites. Double-crested Cormorants are divers, foraging upon fish and aquatic life and, until recently, were restricted to costal environments in Massachusetts but have begun to move inland to inhabit interior lakes and ponds of all sizes. These birds use littoral habitats for foraging and nest in trees or on the ground in shoreline areas or on islands.

Water Shrews can be found in and around the margins of lake and pond environments. These tiny mammals forage on aquatic macroinvertebrates, are rarely found more than a few yards from shore, and prefer heavily wooded banks for creating nests. Very little is known regarding the actual distribution of these mammals in Massachusetts, but they have been found in a patchy distribution in a limited number of sites throughout the central portions of the state.

Two snail species, Boreal Marstonia and Boreal Turret Snail, as well as the invertebrates Smooth Branched Sponge and New England Medicinal Leech, are also found in lakes and ponds and included in the list of SGCN. These species inhabit benthic substrates of littoral areas and very little is known regarding their biology or distribution. Each species has only been identified in a few locations statewide. New England Medicinal Leech has not been reported in Massachusetts for more than 25 years.

The list of SWAP species for lakes and ponds includes five freshwater mussel species, including two, Tidewater Mucket and Eastern Pondmussel, which are listed under the MESA. Freshwater mussels are sedentary filter feeders that are generally found in waters not exceeding 25 feet in depth. The larval stages of these organisms (glochidia) attach to the gills or fins of a freshwater fish host, facilitating further development into the juvenile life stage and dispersal into new habitats. Tidewater Mucket and Eastern Pondmussel are largely restricted to coastal plain ponds in southeastern Massachusetts and Cape Cod. The remaining mussel species, Triangle Floater, Alewife Floater, and Eastern Lampmussel, are distributed across broader swaths of Massachusetts, but often in a sporadic and patchy fashion. Conservation of these species requires a broader, more ecosystem-scale approach as they are reliant upon the presence of (sometimes specific) vertebrate host species.

Seven dragonfly and damselfly species (odonates) on the SWAP list are found within and around lake and pond environments. All but one of these species, Comet Darner, are listed under the MESA. Odonates display three distinct life stages: aquatic egg and larval stages, and an adult flying stage. With the exception of Umber Shadowdragon larvae, which prefer unvegetated, rocky substrates, larval odonates are typically found in close association with submerged aquatic vegetation within littoral lake habitats. Upon emergence, adults move briefly to upland habitats to feed and mature before returning to vegetated lake and pond margins to mate. The Scarlet Bluet, Attenuated Bluet, and Pine Barrens Bluet are known from only a limited number of locations, primarily in coastal plain ponds of southeastern Massachusetts and the Cape. The remaining odonate species are more likely to be found throughout the state with known occurrences displaying a sporadic and patchy distribution.

Only one moth species from the SGCN list inhabits lake and pond environments for at least part of its life cycle. The Water-willow Stem Borer inhabits shallow portions of coastal plain ponds, swamps, and abandoned cranberry bogs. Larvae of this species bore into and feed internally upon Water-willow. The dependence of larvae on Water-willow requires that management and conservation strategies undertake a broader, ecosystem based approach. Water-willow Stem Borer is listed under the MESA and their distribution is limited to southeastern Massachusetts and the Cape and Islands.

Twenty-four SGCN plants inhabit lake and pond environments, with all but two listed under the MESA. These species include submerged and emergent aquatic vegetation (13 species) as well as plants that grow on shorelines and mudflats (11 species). The majority of these species display highly restricted distributions, often only a few sites, sometimes in close proximity to each other. This may be a result of limited sampling efforts and difficulty in differentiating species such as the listed pondweeds (*Potamogeton* spp.), but species-specific habitat requirements such as water quality, substrate, light, and flow conditions may also play a role.

The plants of greatest conservation concern associated with lakes and ponds are a mix of shore and open-water species. Of the shore species, many are dependent on inundation early in the growing season with gradual drawdown of the water over the course of the summer before flowering will occur, and may not reproduce sexually for years if this does not occur. An example is the Resupinate Bladderwort, which is frequently observed flowering in coastal plain ponds that regularly have summer drawdowns, but rarely flowers in large inland lakes and ponds, where it may also occur. Many of the true aquatic species, the pondweeds and water-milfoils, have specific pH requirements for the lakes that they inhabit. For example, Slender Water-milfoil is only found in acidic water, while Straight-leaved Pondweed is only found highly calcareous alkaline waters.

Table 4-20: Species of Greatest Conservation Need in Lakes & Ponds

Taxon Grouping	Scientific Name	Common Name
Fishes	*Alosa pseudoharengus*	Alewife
	Anguilla rostrata	American Eel
	Catostomus commersoni	White Sucker
	Enneacanthus obesus	Banded Sunfish
	Etheostoma fusiforme	Swamp Darter
	Gasterosteus aculeatus	Threespine Stickleback
	Luxilus cornutus	Common Shiner
	Notropis bifrenatus	Bridle Shiner
Amphibians	*Lithobates pipiens*	Northern Leopard Frog
Reptiles	*Pseudemys rubriventris*	Northern Red-Bellied Cooter
	Thamnophis sauritus	Eastern Ribbonsnake
Birds	*Anas discors*	Blue-winged Teal
	Anas rubripes	American Black Duck
	Gavia immer	Common Loon
	Haliaeetus leucocephalus	Bald Eagle
	Phalacrocorax auritus	Double-crested Cormorant
	Podilymbus podiceps	Pied-Billed Grebe
Mammals	*Sorex palustris*	Water Shrew
Misc. Invertebrates	*Macrobdella sestertia*	New England Medicinal Leech
	Spongilla aspinosa	Smooth Branched Sponge
Snails	*Marstonia lustrica*	Boreal Marstonia
	Valvata sincera	Boreal Turret Snail
Mussels	*Alasmidonta undulata*	Triangle Floater
	Anodonta implicata	Alewife Floater
	Lampsilis radiata	Eastern Lampmussel
	Leptodea ochracea	Tidewater Mucket
	Ligumia nasuta	Eastern Pondmussel
Odonates	*Anax longipes*	Comet Darner
	Enallagma carunculatum	Tule Bluet
	Enallagma daeckii	Attenuated Bluet
	Enallagma pictum	Scarlet Bluet
	Enallagma recurvatum	Pine Barrens Bluet
	Rhionaeschna mutata	Spatterdock Darner
	Neurocordulia obsoleta	Umber Shadowdragon
Lepidoptera	*Papaipema sulphurata*	Water-willow Borer
Plants	*Carex lenticularis*	Shore Sedge
	Cyperus engelmannii	Engelmann's Flatsedge
	Elatine americana	American Waterwort
	Eleocharis ovata	Ovate Spike-sedge
	Juncus filiformis	Thread Rush
	Liparis loeselii	Loesel’s Twayblade
	Lipocarpha micrantha	Dwarf Bulrush
	Ludwigia sphaerocarpa	Round-fruited Seedbox
	Myriophyllum alterniflorum	Slender Water-milfoil
	Myriophyllum farwellii	Farwell's Water-milfoil
	Myriophyllum pinnatum	Pinnate Water-milfoil
	Myriophyllum verticillatum	Whorled Water-milfoil
	Orontium aquaticum	Golden Club
	Potamogeton confervoides	Tuckerman’s Pondweed
	Potamogeton friesii	Fries' Pondweed
	Potamogeton gemmiparus	Budding Pondweed
	Potamogeton hillii	Hill's Pondweed
	Potamogeton ogdenii	Ogden's Pondweed

Taxon Grouping	Scientific Name	Common Name
	Potamogeton strictifolius	Straight-leaved Pondweed
	Potamogeton vaseyi	Vasey's Pondweed
	Rotala ramosior	Toothcup
	Sclerolepis uniflora	One-flower Sclerolepis
	Sparganium natans	Small Bur-reed
	Utricularia resupinata	Resupinate Bladderwort

Threats to Lakes and Ponds

IUCN Threat 1: Residential and Commercial Development
Residential and commercial development on or adjacent to shorelines or within submerged nearshore areas can result in the simplification and loss of littoral and riparian habitat. Aquatic vegetation and woody debris removal and the construction of seawalls, beaches, and other structures often results in homogenized, less complex aquatic habitats. Furthermore, the filling of wetlands to create suitable building sites eliminates aquatic habitat entirely and necessary shore habitat needed by the listed plants. Noise associated with such construction activities may also be harmful to fish species (Slabbekoorn et al. 2010). Development in terrestrial areas of the riparian zone can degrade or result in the loss of habitat which can disrupt aquatic-terrestrial linkages. Furthermore, impervious surface within a watershed, but particularly when located in close approximation to a waterbody, has been correlated to changes in hydrologic functioning, reduced water quality, increased nutrient loading and sedimentation, increased salinization, and changes in surface water temperatures. Development may also be associated with nutrient enrichment and pesticide pollution and will be covered under IUCN Threat 9: Pollution.

Littoral habitats provide at least one critical habitat, such as foraging, rearing, spawning, or refuge habitat, for one or more life stages of many animal species listed above. For example, White Sucker, Banded Sunfish, Swamp Darter, Threespine Stickleback, and Common Shiner use littoral habitats to meet most or all of their annual habitat requirements (Hartel et al. 2002). As such, degradation, simplification, or removal of such habitats can result in decreases to the growth or abundance of these organisms. For species with both aquatic and terrestrial life stages, or ones where critical habitats span aquatic-terrestrial boundaries, such as birds, odonates, Water Shrew, Eastern Ribbonsnake, Northern Red-Bellied Cooter, and Northern Leopard Frog, the potential consequences of development can be greater and occur much faster, as degradation to, or the loss of either habitat type can result in detrimental effects. Threats to plant species include removal, homogenization of littoral areas, modification of substrate, and habitat loss.

IUCN Threat 2: Agriculture and Aquaculture
Impacts of agriculture include non-point source nutrient pollution and pesticide inputs, which will be addressed under IUCN Threat 9: Pollution. Furthermore, surface and groundwater withdrawal for agricultural purposes may remove water directly from, or intercept water contributing to, lake and pond environments, resulting in reduced water levels. These activities are regulated by the Massachusetts Department of Environmental Protection under the Wetlands Protection Act and the Water Management Act. If severe, these activities can dewater nearshore littoral habitats, reducing the amount of habitat available to organisms. Water withdrawal can also reduce the moisture level in soils, which may result in the decline of plant species dependent on such conditions. Such water withdrawals do not always follow natural cycles. When out of sync with the normal progression of high water in spring and gradual lower water levels over the summer growing season, plant species may be dried and flooded beyond their ability to tolerate such events.

IUCN Threat 3: Energy Production and Mining
The incineration of coal, as well as gold and other metal mining and ore processing activities, can put large quantities of mercury into the environment. This and mercury produced from natural sources such as volcanoes, geologic deposits, and others can enter the food chain and bioaccumulate within higher trophic

levels. Piscivorous bird species such as Common Loon, Bald Eagle, Double-crested Cormorant, and Pied-Billed Grebe may be at particular risk due to the large quantities of fish they consume. While Massachusetts has only one remaining coal-fired power plant (Brayton Point, scheduled to close in 2017), it is still affected by mercury from closed plants and from active power plants elsewhere (see Evers et al. 2012 for a larger discussion of mercury in northeastern ecosystems).

IUCN Threat 4: Transportation and Service Corridors
The movement of cars, trains, or other conveyances across causeways or on infrastructure or unimproved surfaces adjacent to lakes and ponds represent a significant vector by which invasive organisms may enter such environments. Seeds or other plant material entrained on vehicles or boats may be spread great distances in relatively short periods of time if dislodged. This topic will be covered in greater detail under IUCN Threat 8: Invasive and Other Problematic Species and Genes.

Causeways and other transportation corridors located near lakes and ponds may also fragment habitats and disrupt aquatic-terrestrial linkages. This may be most disrupting to odonate species which have aquatic larval stages and flying adult stages requiring adjacent upland forest habitat in which to mature. Causeways also have the potential to block fish movements across waterbodies, and disconnect critical habitat types such as spawning and rearing from foraging habitats. If transportation corridors are located in close proximity to critical habitats, organisms may be deterred from these areas by anthropogenic noise. Noise from transportation corridors or boat ramps may also interrupt critical behaviors such as spawning or other reproductive activities, and cause stress related reductions in growth or reproductive output (Slabbekoorn et al. 2010). Boat ramps may also be areas of concern due to the continual disturbance of substrates and the potential for introduction of pollutants from vehicles and boats.

IUCN Threat 5: Biological Resource Use
New regulations (January, 2015) now prohibit the harvest of any fish from the inland waters of the Commonwealth for commercial use, so there is very little threat to fish from biological resource use. Further, species listed under the MESA cannot be captured or taken without special permit. However, native invertebrates are not protected by hunting and fishing statutes in Massachusetts, and therefore the collection of invertebrates is not regulated if they do not fall under the MESA. The extent of commercial collection of freshwater mussels and odonates in Massachusetts is not currently known, but does occur.

IUCN Threat 6: Human Intrusions and Disturbance
Recreational use of lake and pond environments, by boat or on foot, can degrade habitat and in some cases destroy species of concern. Wave action created by boats can wash over large percentages of fragile emerging dragonflies and damselflies, resulting in mortality. Picnickers, hikers, and fishermen can trample plants and Water Shrew burrows and disrupt nesting Bald Eagles, potentially resulting in nest abandonment. Rare spike-sedges often occur in areas of low-gradient shores, which are preferred access points for fishermen and recreational users. Substrate disturbance resulting from recreational activities can harm mussel species in shallow littoral areas. Discarded lead sinkers (now banned in Massachusetts) and other garbage may be consumed by fish and bird species.

Off-road-vehicle use in riparian areas and within lakes and ponds can be destructive to physical habitat and reduce water quality. Further, the activities related to shoreline development and recreation in lakes and ponds can affect habitat of rare mussels and odonates. Nedeau (2009) examined the effect of docks on freshwater mussels in southeastern Massachusetts ponds. While there was no correlation between the presence of docks and absence of rare mussels, there were significantly fewer rare mussels in areas of developed shorelines than undeveloped shorelines. Effects of the shoreline development (e.g., runoff) could not be separated from the level of recreational activity that occurs in areas of developed shoreline.

IUCN Threat 7: Natural System Modifications
The water level of some lakes and ponds is manipulated seasonally to protect inundated infrastructure and to control aquatic vegetation within shallow nearshore areas. Drawdowns are recommended to begin no earlier than November 1, achieve target depth by the beginning of December, and be completely refilled by April 1. Drawdowns are limited to 3 feet in depth unless special permission is granted. While drawn down, exposed littoral habitats will desiccate and freeze if subject to appropriate temperatures.

White Sucker, Banded Sunfish, Swamp Darter, Threespine Stickleback, and Common Shiner use littoral habitats to meet most or all of their annual habitat requirements (Hartel et al. 2002). The reduction of littoral habitat in winter may force these fish species into deeper habitats, potentially resulting in greater mortality through predation. Additionally, these species and Alewife spawn in shallow habitats in spring. Northern Leopard Frog and Northern Red-bellied Cooter spend winter in close association with the substrate in littoral habitats of lakes and ponds. Thus these organisms may be stranded in exposed areas if water levels drop too rapidly. Furthermore, Northern Leopard Frog reproduces in spring in shallow weedy habitats. Thus, failure to meet refill goals may result in large reductions in spawning habitat and reproductive success.

The exposure of littoral habitats separates Water Shrew foraging habitat in nearshore aquatic areas from nesting and refuge habitat in lake and pond banks. Greater distances between these critical habitat types may result in increased rates of Water Shrew predation, mortality, and energy consumption. Furthermore, the abundance and diversity of aquatic insects, the primary food of Water Shrew, may decrease as a result of desiccation of nearshore habitats, potentially resulting in reduced rates of growth and survival.

New England Medicinal Leech, Smooth Branched Sponge, and the nymph and egg life-stages of many odonate species occupy nearshore habitats during fall. The limited ability of these species and life stages, particularly odonate eggs, to move could result in stranding on or within exposed substrates if water levels recede quickly. Furthermore, dramatic reductions in nearshore aquatic vegetation resulting from drawdowns may reduce foraging, reproductive, and rearing habit for these organisms.

There is currently a lack of data on the effects of water drawdowns (greater than 3 feet) on native mollusk assemblages, but this practice presents significant alterations to the habitat for these faunal groups. Freshwater mussels occupy littoral habitats and may be affected by standard drawdowns, but also by deeper (i.e., greater than 3 feet) drawdowns, particularly if the drawdown rate is fast. If rates of drawdown are prolonged, then the mussels should adapt to a fall in a water height as they will often retreat to deeper areas as water temperatures drop. If refill goals are not met, habitat for mussels in the spring and summer spawning seasons may be reduced. The concern for drawdowns on snails is more closely related to the loss of foraging habitat. Most snails that occupy lakes and ponds in Massachusetts are associated with submerged aquatic vegetation, where they will graze on epiphytic algae. Losses in submerged aquatic plants may represent a loss in habitat for these snails.

Several of the plant SGCN grow in littoral areas. Dewatering and desiccation of these areas, while aiding in the control of nuisance aquatic vegetation, will also reduce the abundance of SGCN plants as well. Maintenance of a healthy littoral habitat and a natural flow regime is critical for these plant species, including no winter drawdowns.

Herbicides and other chemicals are often applied to many lakes and ponds to control or reduce nuisance aquatic vegetation. Treatments may occur throughout the open water season but are most commonly completed in spring and early summer. Large-scale removal of aquatic vegetation in littoral habitats will reduce spawning, rearing, foraging, and refuge habitat for fishes, potentially resulting in decreased abundances and growth. Similar effects may occur for other species that rely heavily upon the presence of nearshore aquatic vegetation for some or all of their life cycles, such as Northern Leopard Frog, Northern Red-bellied Cooter, New England Medicinal Leech, gastropods, and odonates. Rare plants are also susceptible to herbicides and other chemicals. Furthermore, such large-scale alteration to the habitat and thus ecology of a lake and pond has the potential to restructure biotic communities at multiple trophic levels, resulting in whole-lake changes in community structure. The toxicity of these chemicals will be addressed under IUCN Threat 9: Pollution.

IUCN Threat 8: Invasive and Other Problematic Species and Genes

The introduction of nonnative invasive plants is a major threat to lake and pond environments. These species can outcompete native plant species, permitting rapid proliferation of dense monocultures that in some cases can encompass entire waterbodies. In these instances, the reduction or outright elimination of open-water habitat may be detrimental to piscivorous birds such as Bald Eagle, Common Loon, and Pied-billed Grebe. Exotic plant monocultures may be less suitable habitat to fish, compared to native plant species, and can cause reductions in dissolved oxygen and even fish kills when such plant matter decomposes. The introduction of nonnative invasive willow species around coastal plain ponds may be detrimental to Water-willow Borer, which requires Water-willow to complete its lifecycle. This and other topics germane to coastal plain ponds are covered in the coastal plain ponds section.

As with aquatic plants, the introduction of nonnative animals such as Zebra Mussels (*Dresseina polymorpha*), carp species, Snakehead (*Channa argus*), and others can have devastating effects on the aquatic ecosystem. In the absence of competition, these organisms can become abundant and result in reductions in the abundances of native fauna (Strayer et al. 2014). In some cases, the introduction of nonnative fauna can modify the structure and interactions among multiple trophic levels resulting in changes in community structure and trophic dynamics at large scales (Nicholls et al. 1993).

The Asiatic Clam *(Corbicula fluminea*) has been increasing in distribution in Massachusetts waters, presumably through introduction from bait wells of recreational fishing boats. While potential threats posed to native bivalves has been identified (Vaughn and Spooner 2006), we are currently unaware of convincing documented evidence that Corbicula pose a significant risk to native unionids. Zebra Mussels are established in Laurel Lake (Lee, Massachusetts) and have been found within the Housatonic River downstream of the lake. Zebra Mussels pose significant threats to native unionids when conditions are favorable for expansion (Strayer and Malcom 2007; Strayer et al. 2015) Other Massachusetts state agencies have coordinated a risk assessment of Zebra Mussel invasion of other waterbodies in the state (Nedeau 2010). Water conditions in much of the central and eastern parts of Massachusetts are not predicted to be favorable for Zebra Mussel expansion. Nevertheless, continued cooperation with other agencies and occurrence tracking is warranted for these and other introduced aquatic species (e.g., Spiny Waterflea, *Bythotrephes longimanu;* Rusty Crayfish, *Orconectes rusticus*; Robust Crayfish, *Cambarus robustus*).

Cyanobacteria blooms are becoming more prevalent in Massachusetts lakes and ponds, and have been associated with freshwater mussel kills. The underlying mechanism of mortality is not known but several factors may be involved either together or singularly: 1) algal blooms may reduce dissolved oxygen concentrations leading to acute hypoxia and mussel death (Strayer 2013); 2) as the algal communities in a pond shift from green algae to cyanobacteria, decreased nutritional value may cause a sustained decline in mussel health (Gelinas et al. 2013); and 3) accumulation of cyanotoxins by the mussel results in physiological toxicity and decline in mussel health (Travers et al. 2011).

IUCN Threat 9: Pollution

Nutrient-rich effluents and runoff emanating from residential and commercial development, agricultural lands, impervious surfaces, septic systems, and disturbed soils in proximity to lakes and ponds may enter these environments and contribute to eutrophication. Lakes and ponds in Massachusetts are particularly vulnerable to this type of pollution due to their small size and thus limited ability to uptake large quantities of nutrients. Excess nutrients can fuel excessive plant growth, which settles on lake bottoms, decays, and results in uninhabitable areas of hypoxic conditions. Hypoxic bottom waters can lead to fish kills when these areas extend to the surface or when they envelop critical thermal strata. Hypoxic to near hypoxic conditions may also stress fish, leading to increased susceptibility to disease, parasites, and ultimately death. Eutrophication is also associated with increased turbidity, decreased dissolved-oxygen levels, toxic blue-green algae blooms, and increased sedimentation, which ultimately decreases the depth of a waterbody. Currently, hundreds of waters in Massachusetts do not meet their designated water-quality standards.

Agricultural runoff, pesticides, and use of herbicides to control nuisance aquatic plants further threaten aquatic systems, as aquatic invertebrates, and mussels in particular, are significantly more sensitive to toxicity from herbicides used in agriculture and nuisance aquatic plant management (Milam et al. 2005; Bringolf et al. 2007; Archambault et al. 2014). While separating the effect of one contaminant as being more important than any other is difficult, addressing point and non-point source pollution in aquatic systems is an important component of informed habitat management for aquatic species.

Acidification of waterbodies from atmospheric deposition continues to be a concern throughout the northeastern United States. Alteration of the pH of a waterbody can reduce habitat suitability for sensitive native species. Further, the addition of nutrients from atmospheric deposition (e.g., nitrogen deposition) may also accelerate the effects of eutrophication and change in the ecological function of waterbodies in Massachusetts.

IUCN Threat 10: Geological Events
Volcanoes, earthquakes, tsunamis, avalanches, and landslides do not appreciably threaten lake and pond environments in the relatively short term (100 years).

IUCN Threat 11: Climate Change and Severe Weather
Changes in climate and local weather patterns will likely affect aquatic systems by exacerbating or accelerating habitat degradation due to other identified threats. Extended periods of drought could result in lowered water levels and the loss of littoral habitat. Littoral areas are used for foraging, rearing, reproduction, and refuge by a myriad of species, including mussel, odonate, fish, and invertebrates. Thus, extended periods of drought and the loss of these areas has the potential to reduce the abundance of these species. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface-water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms. As well, increases in snow and ice in the winter can result in more fish kills.

Conservation Actions

Direct Management of Natural Resources
Manage invasive species, erosion, water withdrawals and other threats at high priority sites, such as exemplary coastal plain pond shore communities.

Coordinate with DEP to support the attainment of targeted water-quality standards for all lakes and ponds.

Work with the Department of Conservation and Recreation and with Environmental Law Enforcement to reduce ORV use and creation of new trails in riparian areas of sensitive habitat on state-protected land.

Data Collection and Analysis
Continue research into the efficacy of the Red-bellied Cooter headstarting program, which is believed to be the largest and longest-running program of its kind. Complete statewide population assessment to follow up on intensive field work conducted in the late 1980s and early 1990s.

Conduct surveys of lakes and ponds to assess fish, invertebrate, and plant communities.

Develop and carry out monitoring and de novo sampling of freshwater mussel and odonate communities throughout the state on a 5-year rotation, where one DFW district is targeted per year. Sites or populations of immediate importance may necessitate deviation from the rotation when immediate threats or need to update information is apparent. Continue to track occurrences of invasive invertebrates during native-species surveys.

Surface water and groundwater withdrawals need more research and monitoring on the effects of these actions on water quality in rare-species habitat.

Initiate study to assess the potential effects of lake drawdowns on fish and invertebrate communities.

Continue collaboration between DFW and the USGS Massachusetts Cooperative Fish and Wildlife Research Unit to assess the ecological effects of drawdowns on aquatic fauna. Use research to define science-based management policies on extent and periodicity of drawdowns in habitats of SWAP species.

Coordinate research on the effects of harmful algal blooms on rare aquatic fauna.

Initiate lab and natural studies to assess the toxicity of herbicides to fish and invertebrate species.

Continue to monitor rare-plant populations to determine how or if they are being affected by human activities in and around lakes and ponds, and make recommendations to mitigate impacts.

Education and Outreach
Provide education to town conservation commissions to ensure proper enforcement and interpretation of the Wetlands Protection Act.

Work with other northeastern states to develop standardized freshwater-mussel population-assessment approaches, based on previously published methodologies and data reporting, to better understand the region-wide threats to mussel conservation.

Encourage invasive species data reporting from other agencies, consultants, and academics. Collaborate with other state agencies toward information sharing and strategic planning on invasive species prevention and control. Work with other state agencies to define invasives of greatest risk, and collaborate as needed to find funding for research and conservation action for species that pose the greatest threats.

Educate the public as to the dangers of releasing nonnative plants and animals into lakes and ponds. Collaborate with stakeholders, municipalities, DEP, DCR, and DPH to identify best management practices for control of harmful algal blooms, to aid in protection of rare aquatic fauna.

Coordinate with other state agencies and municipalities to reduce inputs of nutrients, sediment, and organic pollutants to state waterbodies.

Educate and inform the public about the values of these habitats and the issues related to their conservation, through agency publications and other forms of public outreach, in order to instill public appreciation and understanding.

Educate the public and conservation partners about the need to actively manage habitat in some cases in order to maintain SWAP species and natural communities such as coastal plain pond shores.

Harvest and Trade Management
Work with biological supply companies to determine methods, extent, and species collected for commercial purposes through voluntary reporting. Educate collectors on proper species identification.

Enforce the newly adopted (2015) ban on commercial harvest of baitfish in Massachusetts.

Land and Water Rights Acquisition and Protection
Protect land around lakes and ponds supporting populations of rare and uncommon SWAP species.

Law Enforcement
Monitor lake drawdown activities to assure target depths are not exceeded and refill dates are met.

Monitor herbicide applications to assure such applications are conducted in accordance with regulation and safety protocols.

Coordinate with municipalities and DEP to ensure surface and groundwater withdrawals are within the guidelines of the State Water Management Initiative and the Wetland Protection Act.

Coordinate with DCR to include new invasive species on the formal list of Aquatic Invasive Species for regulatory inclusion under the Act to Protect Lakes and Ponds and DCR Regulations under the Aquatic Nuisance Control Program (302 CMR 18.00).

Regulate and limit the impacts of development on lakes and ponds used by MESA-listed species.

Review all regulated construction projects to ensure adherence to proper Best Management Practices for erosion and sedimentation control and other required conditions.

Enforce relevant regulations, including the newly adopted (2015) ban on commercial harvest of baitfish in Massachusetts and the ban on the use of lead sinkers in recreational fishing.

Law and Policy
Continue to work with DEP, using established risk assessment approaches, to devise performance standards for aquatic herbicide uses protective of freshwater mussels and other aquatic invertebrates.

Planning
Develop detailed conservation and recovery plans for SGCN associated with lakes and ponds. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Continue Red-bellied Cooter headstarting program, while evaluating its expected duration and next steps.

Evaluate the proposal by nonprofit conservation partner to reestablish Bridle Shiner in lakes and ponds where it has been extirpated.

Collaborate with other northeastern states, federal agencies, and academic institutions to assess the feasibility of a freshwater-mussel propagation facility in New England. Provide technical expertise, research, and conservation direction to the development of restoration and reintroduction methods for freshwater mussels.

Links to Additional Information

- Massachusetts Dept. of Conservation and Recreation's Lakes and Ponds Program
- Fact sheets on aquatic invasive plants common in Massachusetts

Salt Marsh

Habitat Description

Located between the high spring tide and mean tide levels of protected coastal shores, salt marshes comprise one of the most productive ecosystems on earth. In spite of the stresses of wide variations in temperature, level of salinity, and degree of inundation, the salt-tolerant vegetation of the salt marsh community provides the basis of the complex food webs in both estuarine and marine environments. In addition, salt marshes provide habitat for various species of wildlife, including migrating and overwintering waterfowl and shorebirds and the young of many species of marine organisms.

In the northeastern United States, salt-marsh communities are dominated by two species of perennial, emergent grasses that are adapted to growth in salty soils, Saltmarsh Cordgrass (*Spartina alterniflora*) and Saltmeadow Cordgrass (*Spartina patens*). While these dominant species give the community a deceptively simple, grassland-like appearance, salt marsh systems are heterogeneous and provide a variety of habitats. Low marshes flood with salt water in every tide and are only exposed for brief periods during low tide. High marshes, on the other hand, are submerged only during the highest tides. Shrubby areas (salt shrub) are on slightly higher areas within the marsh or towards the upper edges. Slightly lower areas within the marshes can form salt pannes where seawater is held as tides recede. When the salt water evaporates, a salt crust is left on bare ground; as open areas in the marsh, pannes are important to migrating waterfowl.

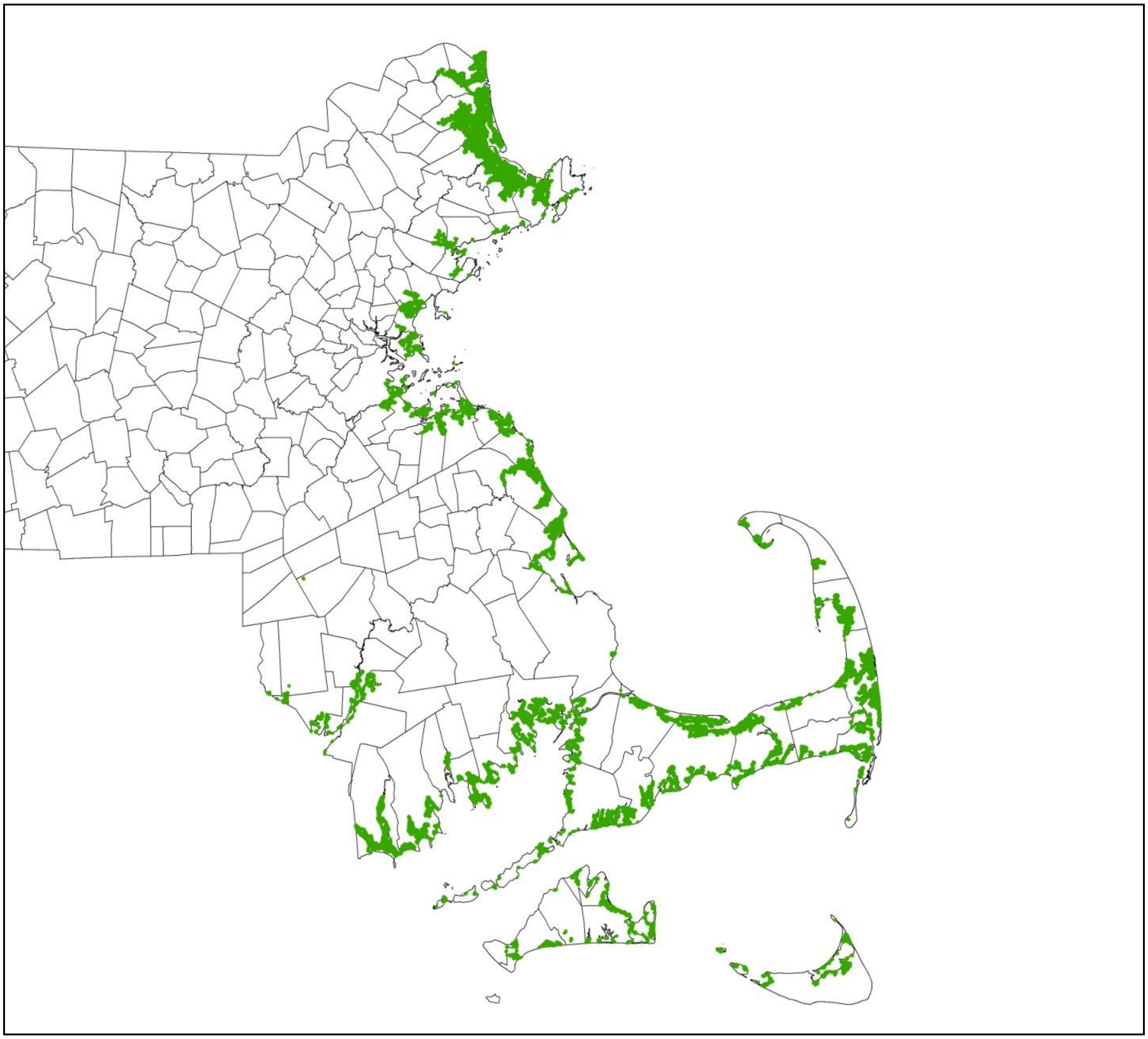


Figure 4-26: Extensive Areas of Salt Marsh in Massachusetts.

Species of Greatest Conservation Need in Salt Marsh

Thirty-two SGCN are assigned to the Salt Marsh habitat (Table 4-21).

Numerous species of birds use salt marshes in all seasons. In particular, many shorebirds, including American Oystercatcher, Willet, Killdeer, and Spotted Sandpiper, forage there. In summer, wading birds (Snowy Egrets, Glossy Ibis) feed in pools at low tide. American Black Ducks use salt marshes for both nesting and wintering habitats. A few species, such as Seaside Sparrow, Saltmarsh Sparrow, and Willet, nest there as well, as do occasional Least Bitterns and Common Terns. Short-eared Owls, Barn Owls, Snowy Owls, and Northern Harrier use salt marshes for hunting small mammals and other prey. Terns are colonial nesters on ocean beaches on islands and spits, areas often in or near salt marshes, and salt marshes are used by all the tern species for loafing (resting) and providing important cover for their mobile young. Specifically, Least and Common terns nest in high spots within salt marshes, and Roseate Terns nest adjacent to salt marshes.

In fact, many animals use the abundant resources of the salt marsh. Marine species such as polychaete worms, snails, small crustaceans, and filter-feeding mussels dwell in the low marsh. Various insects graze on the vegetation or spend their larval stage in the mud. The larvae of two state-listed moths are specialists on plant species that predominantly occur in salt marshes and their brackish upper reaches (in Massachusetts), and so are restricted to these habitats. Larvae of one of these moths, the Cordgrass Borer, feed exclusively on Prairie Cordgrass (*Spartina pectinata*) growing in brackish and freshwater marshes. With the incoming tide, fish and crabs move in to feed. Few mammals are resident in salt marshes, but raccoons and meadow voles use them, retreating to drier areas during high tides.

Tidal creeks, which facilitate the flooding and drainage of the marsh, have their own distinct flora and fauna. Fiddler crabs are invertebrates often found in salt marsh creeks. Common fish in tidal creeks include Mummichog, Four-spined Stickleback, and Striped Killifish.

Northern Diamond-backed Terrapins use salt marshes and mud flats that border quiet salty or brackish waters, and nest in nearby open and dry sandy areas. They hibernate by burying into the substrate of nearby estuary channels, among other sheltered wetlands, during the winter months. Salt marshes themselves are critical habitat for juvenile terrapins.

Several rare plants are associated with salt marshes in specialized areas. Mitchell's Sedge and Saltpond Grass occur in salt marshes where there are freshwater seeps. Bristly Foxtail, Salt Reedgrass, and Northern Gama-grass may be found on the sandy-gravelly substrates at the edges beyond the reach of high tides but exposed to storm surges, wind, and salt spray. Rich's Sea-blite will be within the salt marsh and Saltpond Pennywort may be found in areas with permanent inundation.

Table 4-21: Species of Greatest Conservation Need in Salt Marshes

Taxon Grouping	Scientific Name	Common Name
Fishes	*Fundulus luciae*	Spotfin Killifish
Reptiles	*Malaclemys terrapin*	Northern Diamond-backed Terrapin
Birds	*Ammodramus caudacutus*	Saltmarsh Sharp-tailed Sparrow
	Ammodramus maritimus	Seaside Sparrow
	Ardea alba	Great Egret
	Anas rubripes	American Black Duck
	Asio flammeus	Short-eared Owl
	Calidris pusilla	Semi-palmated Sandpiper
	Egretta thula	Snowy Egret
	Larus argentatus	Herring Gull
	Larus atricilla	Laughing Gull
	Larus marinus	Great Black-backed Gull
	Nycticorax nycticorax	Black-crowned Night-Heron
	Plegadis falcinellus	Glossy Ibis
	Sterna dougallii	Roseate Tern
	Sterna hirundo	Common Tern
	Sterna paradisaea	Arctic Tern
	Sternula antillarum	Least Tern
	Sturnella magna	Eastern Meadowlark
	Tringa semipalmata	Willet
	Tyto alba	Barn Owl
Snails	*Floridobia winkleyi*	New England Siltsnail
	Littoridinops tenuipes	Coastal Marsh Snail
Lepidoptera	*Neoligia semicana*	Northern Brocade Moth
	Photedes inops	Cord-grass Borer
Plants	*Carex mitchelliana*	Mitchell's Sedge
	Hydrocotyle verticillata	Saltpond Pennywort
	Leptochloa fusca ssp. *fascicularis*	Saltpond Grass
	Setaria parviflora	Bristly Foxtail
	Spartina cynosuroides	Salt Reedgrass
	Suaeda maritima ssp. *richii*	Rich's Sea-blite
	Tripsacum dactyloides	Northern Gama-grass

Threats to Salt Marshes

IUCN Threat 1: Residential and Commercial Development
Since the arrival of the first Europeans, Massachusetts has lost a large portion of its salt-marsh habitat. The Boston area was originally the site of an extensive salt marsh, most of which was destroyed by the dredging and filling of the Back Bay. Between the end of World War II and the mid-1970s, Massachusetts lost approximately 20,000 acres of salt marsh, a third of the total acreage it had at the beginning of this period. Fortunately, little development now occurs in salt marsh areas.

Runoff from septic systems and stormwater discharges from residential and commercial development still affects salt marshes, and can lead to eutrophication of these areas, displacing both plant and animal SGCN.

IUCN Threat 2: Agriculture and Aquaculture
Pollution from agricultural runoff (fertilizers, herbicides, pesticides) has been found to degrade salt-marsh habitat (see pollution section below; Deegan et al. 2012). Haying poses a potential threat to the salt marsh, but this appears to be minimal in Massachusetts. Saltmarsh haying is only conducted on a commercial scale in the Plum Island Sound region,

and this is typically done every few years from late July through fall or even into winter. However, if haying were conducted in June, it would likely result in the destruction of any active bird nests. Several of the plant species associated with salt marshes are tall grasses: Saltpond Grass, Bristly Foxtail, Salt Reedgrass, and Northern Gama-grass. These species could not withstand active haying on a yearly basis.

IUCN Threat 3: Energy Production and Mining
Energy production and mining are not a major threat to salt marshes in Massachusetts.

IUCN Threat 4: Transportation and Service Corridors
A major threat to salt marshes, currently and in the near future, is the blockage by roads and other infrastructure to the upslope migration of salt marshes affected by rising sea levels.

Dredging of navigation channels and harbors immediately adjacent to salt marshes has the potential to disrupt and harm overwintering terrapins.

IUCN Threat 5: Biological Resource Use
Crab pots and derelict fishing gear pose a threat to Northern Diamond-backed Terrapins (Radzio et al. 2013; Baker et al. 2013; Bilkovic et al. 2014). The threat is not believed to be high in Massachusetts at this time, due to relatively little commercial or recreational crabbing. High-intensity fishing also has the potential to result in other system changes (see IUCN Threat 7 below).

IUCN Threat 6: Human Intrusions and Disturbance
These areas tend to have high human activity near them. Paths and roads near plant SGCN populations can result in trampling of those species near the edge of salt marshes.

IUCN Threat 7: Natural System Modifications
Current threats to salt marshes include some development, dredging for docks and marinas, tidal restrictions, and ditching for mosquito control, all of which change the hydrodynamics and hence the viability of the community and the habitat for the animals. High-intensity fishing has reduced predators in many salt marshes, allowing native Sesarma crabs to increase to the point of causing browning, dramatic die-offs of cordgrass, and accelerated erosion of many salt marshes.

Woody-shrub encroachment is a problem for Bristly Foxtail and Salt Reedgrass, as these species are often near the edges of the salt marsh.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Invasive species are another important threat to salt marshes, especially where the normal tidal influence has been altered. The upland edges of many salt marshes have dense areas of the invasive variant of Common Reed (*Phragmites australis*), as do brackish tidal marshes in several rivers. Perennial Pepperweed (*Lepidium latifolium*), a relatively recent invader, can form monocultures displacing native salt-marsh vegetation. Purple Loosestrife (*Lythrum salicaria*) is established in some of the fresher parts of many salt-marsh systems, adding a shrub-like aspect to the habitat that previously would not have been present. While this increases habitats for some abundant upland species, specialists in the graminoid-dominated marshes lose habitat. The increasingly invasive Mute Swan is becoming more abundant and displacing native species from salt ponds surrounded by salt-marsh habitat. Bristly Foxtail, Salt Reedgrass, and Northern Gama-grass are very sensitive to potential displacement by invasive Common Reed.

IUCN Threat 9: Pollution
Current threats from pollution include contaminated stormwater runoff from adjacent wetlands and potential oil spills in the region. Salt marshes are particularly vulnerable to oil spills because they are not only difficult to clean following the spill, but can trap and retain large amounts of oil. Nutrient enrichment from storm water runoff, especially of nitrogen and phosphorus, at levels that exceed native vegetation’s ability to process it leads to rapid degradation of salt-marsh systems (Deegan et al. 2012). Heavy metals (e.g., mercury, lead, and aluminum from industry, combustible engines, and lawn herbicides and pesticides) in stormwater runoff can also threaten the salt marsh. Saltpond Grass is particularly susceptible to changes in water chemistry.

Discharges from wastewater-treatment plants and faulty septic systems into salt-marsh habitats is a problem for the species that occur there, and can lead to high levels of eutrophication. This leads to algal blooms and other vegetative overgrowth that competes with native plants.

IUCN Threat 10: Geological Events
Geological events are not a major threat to salt marshes in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Salt marshes are also particularly vulnerable to a warming climate that is predicted to result in substantial sea-level rise in the coming decades. While salt marshes are constantly accreting, it is unclear if they can accrete as rapidly as sea levels are rising. When not prevented by roads, bedrock, or structures from migrating landward, salt marshes will increase their footprints. However, the rapidity of such change and the vast amount of development behind many salt marshes will present a major challenge for a natural landward retreat of the habitat. Additionally, the predicted increases in large storm events can impose damage (e.g., destabilize sediments, erosion, flooding) on the salt marsh that can threaten its persistence. Of course, the presence of salt marshes during such storm events is extremely important in mitigating the storm surge and reducing coastal flooding.

All of the plant SGCN may be impacted by severe weather and sea-level rise. As the water chemistry and depth changes, these plants may no longer survive in their current locations. Saltpond Pennywort is currently at its northern extent, so it might increase as the climate warms. A rise in sea level is predicted to result in loss of salt marshes as they become permanently inundated with seawater. As a result, rare salt-marsh plants may be lost if they cannot track salt-marsh habitat as quickly as it is lost in some locations and reestablished in others.

Conservation Actions

Direct Management of Natural Resources
Continue to intensively manage human activities in or near salt marshes supporting breeding colonies of terns.

Manage populations of plant SGCN in and near salt marshes, and to work with conservation partners to encourage management of these species on their properties. Determine the effects of invasive plants and animals on habitats of native species, and evaluate and implement possible management or restoration actions as necessary. This includes *Phragmites* control during early stages of invasion to prevent large, costly control projects.

Work with Mass Audubon and other partners to manage important terrapin nesting sites.

Data Collection and Analysis
Survey for SGCN salt marsh invertebrates to determine their range, abundance, and distribution in the state, as these species are undersurveyed in Massachusetts.

Survey breeding populations of uncommon salt marsh birds (e.g., Saltmarsh Sparrow, Willet) to determine their distribution and abundance in the state, changes in these populations over time, and the need for protection of these breeding populations under the MESA.

Work with the Saltmarsh Habitat and Avian Research Program (SHARP) to monitor salt marsh breeding birds and evaluate the effects of climate change on their populations, ecology, and breeding success.

Research the rapid changes to salt marsh biota related to climate disruption such as the arrival at the Great Marsh of marsh and fiddler crabs in very recent years.

Work with Mass Audubon and other partners to monitor the abundance, distribution, and trends of Massachusetts terrapin populations.

Pursue opportunities to continue research into the potential effects of dredging on terrapin populations.

Education and Outreach
Educate and inform the public about the value of salt marsh habitats and the issues related to their conservation, through agency publications and other forms of public outreach, in order to instill public appreciation and understanding.

Work with Mass Audubon and other partners to engage volunteers in terrapin habitat management and conservation.

Harvest and Trade Management
Assess and monitor threat levels associated with crabbing and derelict fishing gear on terrapin populations.

Land and Water Rights Acquisition and Protection
Protect salt marshes supporting populations of SGCN animals and plants, with particular emphasis on adjacent uplands buffering salt marshes, to provide for potential upslope salt marsh under climate change.

Law Enforcement
Regulate and limit the impacts of development on salt marshes used by state-listed animals and plants.

Law and Policy
Identify dam, ditch, and culvert removal as primary restoration tools and encourage removal of dams, ditches, and culverts.

Planning
Develop detailed conservation and recovery plans for SGCN associated with salt marshes. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Continue to work with the Parker River Great Marsh partnership to identify, through research and modeling, the principal threats to salt marsh conservation, prioritize and address threats systematically.

Species Reintroduction and Stocking
Research the potential of reintroducing plant SGCN in areas where the appropriate management can be accomplished into the foreseeable future. Expanding Northern Gama-grass populations has been discussed with some of the conservation partners on Martha's Vineyard, and may be appropriate with other of the plant species.

Link to Additional Information

- A video series on Phragmites in the Great Marsh of Massachusetts
- Great Marsh Coalition – organizations allied to preserve, restore, and steward the Great Marsh
- Great Marsh Western Hemisphere Shorebird Reserve
- Great Marsh Important Bird Area
- Sandy Neck Important Bird Area

Coastal Dunes, Beaches, and Small Islands

Habitat Description

Much of the coastline of Massachusetts — the second-longest coastline in the eastern United States — is sandy beaches and dune systems. In some places, these form barrier beaches, with extensive estuaries and salt marshes inland of the dunes. Examples of these are Plum Island, Crane Beach, Sandy Neck, and outer Cape Cod. In some places, high steep cliffs of clay, sand, or gravel line the inland edge of the outer beach. In addition to the very large islands of Nantucket and Martha's Vineyard, there are many other small-to-large rocky or sandy islands off the coast in numerous places, notably the Elizabeth Islands, the Boston Harbor islands, and islands off the North Shore. All these habitats support a variety of rare and uncommon animals and plants, most specialized for life only in these areas.

Maritime Beach Strand Community

This is the classic upper beach, familiar to all who have visited the coast. Sparsely vegetated, this long, narrow natural community is usually part of a barrier-beach system, seaward of the dunes; this part of the beach is above the daily high tides and is highly dynamic. However, beach strands are subject to overwash during storms and spring tides and are continuously reshaped by wind and water. Beach strands may be separated from the mainland by dunes, salt marshes, salt ponds, and other estuarine wetlands. Beach-strand communities above the high-tide line support sparse plants.

Marine Intertidal Gravel/Sand Beach Community

Marine beaches are exposed between high tides: They occur below the wrack line and above permanent water and are often interspersed with low areas that contain intertidal pools. These are high-energy habitats. Marine beaches have only sparse cover of nonvascular plants. Invertebrates are the most abundant resident group, with shorebirds among the most visible animals in the habitat.

Maritime Erosional Cliff Community

These sand or clay sea cliffs are composed mostly of glacially derived sands, cobbles, and boulders eroded by the sea and percolating groundwater, especially during storms. Active erosion of the cliffs by wind and waves dictate slope and stability at any given moment. While vegetation is generally very sparse on these cliffs, it is most diverse where freshwater seepage emerges through the bluff and in areas with low relief.

Maritime Dune Community

This is the classic community of sand dunes, dominated by dune grass (*Ammophila breviligulata*) and interspersed with patches of bare sand, lichens, herbaceous plants, and shrubs. In well-developed systems, interdunal swales occur. The maritime-dune community occurs on windswept dunes, within the salt spray zone, often landward of the beach-strand community and grading into shrubland, heathland or woodland on the more sheltered back dunes. Dunes are deposited by wind, water, and storm over-wash. The propensity of dunes to move over time as a result of wind and waves is an important component of this dynamic habitat.

Maritime Pitch Pine on Dunes Community

These are dynamic communities dominated by pitch pine (*Pinus rigida*) on open areas of sand with lichens and some scattered shrubs and herbaceous plants. Communities are typically small and often linear, occurring on coastal dunes created and maintained by the movement of sand by wind. Though the community typically occurs in back-dune settings out of the daily influence of salt spray, storm-driven salt spray is likely a key factor in maintaining the community free of generalist species.

See Swain and Kearsley (2015) for more detail on these five natural communities.

Small islands off the Massachusetts coast are varied in their composition. Some are small sandy or cobbly bars, just barely above high tide. Some are resistant bedrock, with steep rock cliffs dropping directly into the ocean. Some harbor short, wind-twisted trees, but many are grassy or shrubby, in part due to wind and salt spray, but also because many islands were historically cleared of timber and used for grazing or agriculture. Often, these cleared islands have not yet reverted to woodlands, and may never do so.

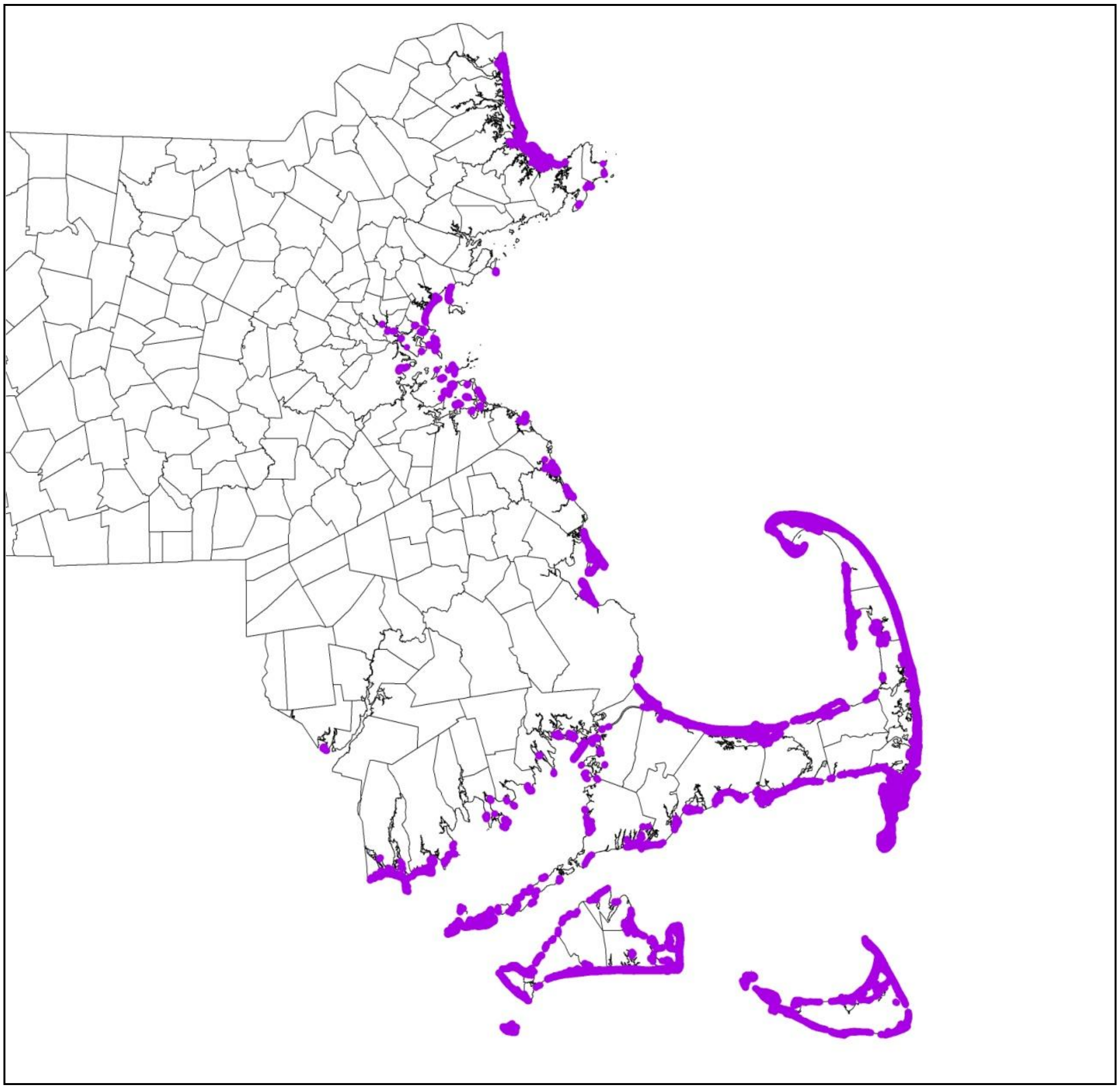


Figure 4-27: Coastal Dunes, Beaches, and Small Islands in Massachusetts.

Species of Greatest Conservation Need on Coastal Dunes, Beaches, and Small Islands

Forty-eight SGCN are assigned to the Coastal Dunes, Beaches, and Small Islands habitat (Table 4-22).

Several species of shorebirds and seabirds, notably Least Tern, Piping Plover, and American Oystercatcher, nest on beach strands. Beach strands and associated intertidal zones support large flocks of migratory shorebirds as well as massive post-breeding concentrations of staging Roseate Terns and Common Terns, which loaf and roost on the beaches and in the intertidal zone. Invertebrates in the marine intertidal zone support these bird species, including nesting Piping Plovers feeding on marine worms and amphipods, as well as transient Red Knots feeding on mussel spat. Merlins (*Falco columbarius*) and Peregrine Falcons (*Falco peregrinus*) forage on beaches and islands during migration. Mid-sized predators, such as Red Fox (*Vulpes vulpes*), Striped Skunk (*Mephitis mephitis*), Raccoon (*Procyon lotor*), and Coyote (*Canis latrans*), are often present on the beach, occasionally denning and regularly foraging, incorporating into their diets invertebrates, ground-nesting seabirds and shorebirds (including their eggs and young), and human refuse. Crows, gulls, Black-crowned Night-Herons, and both nocturnal and diurnal raptors also forage on beaches and, like mammals, can severely disturb and depredate nesting coastal waterbirds. The salt marshes on the bay sides of barrier beaches support nesting and foraging Willets and oystercatchers. At low-disturbance sites, Gray Seals (*Halichoerus grypus*) bear their young and rest on the beach; beach resting by seals of other species (mostly Harbor Seals, *Phoca vitulina*) is frequent. Northeastern Beach Tiger Beetles inhabit the upper beach as burrowing larvae and breeding adults, and forage on both the upper beach and in the intertidal zone. Invertebrate specialists are numerous and include several species of beetles, beach flies, and amphipods; on the south side of Cape Cod, Ghost Crabs (*Ocypode quadrata*) reach their northern limit of distribution. Seabeach Needle-grass, Broom Crowberry, Sea Lyme-grass, Oysterleaf, Eastern Prickly Pear, Sea-beach Knotweed, Seabeach Dock, Bristly Foxtail, American Sea-blite, and Rich's Sea-blite are all found on beaches and beach strands. Some, such as Sea-beach Knotweed, are typically found in over-wash areas from storm surges into coastal ponds and bays.

The upper portions of sea cliffs are used for nesting by Bank Swallows (*Riparia riparia*) and as perch and hunting locations for Peregrine Falcons during migration. Gulls, terns, and cormorants nest on cliff faces. Adult Claybank Tiger Beetles inhabit the beach at the base of clay sea cliffs, and their burrowing larvae inhabit the clay cliffs above.

Terns, gulls, shorebirds, and songbirds nest on the dunes and in the interdunal area. Dune overwash events are vital for maintaining habitat for species like the Piping Plover and Least Tern, which prefer very sparse vegetation and flat or gently sloping beaches, including interdunal overwash fans. More stable dune areas in which shrub patches occur support nesting egrets, herons, and gulls. Eastern Whip-poor-wills nest in maritime shrublands and woodlands, and Maritime Dune Communities support the few pairs of breeding Common Nighthawks in the state. Dunes are also extremely important to migratory birds for food and cover during migration. Diamondback Terrapins use dunes for nesting. Moths inhabiting stable dunes with shrub patches include the Chain-dotted Geometer and Dune Sympistis. Northeastern Beach Tiger Beetles overwinter in the dunes. Bristly Foxtail, Broom Crowberry, and Eastern Prickly Pear are found in the back dunes, well away from the normal reach of high tide. These species prefer dry, open, sandy habitats in full sun with occasional disturbance, possibly in the form of storm-surge over-wash, fire, or windstorms.

Small coastal islands can support all of these sandy natural communities, as well as many other habitats, but they are most important as refuges for colonial-nesting waterbirds that cannot persist at sites where mammalian and avian predation is high. Such highly sensitive species include Leach's Storm-Petrel, Double-crested Cormorant, Snowy Egret, Great Egret, Black-crowned Night-Heron, Glossy Ibis, Laughing Gull, Great Black-backed Gull, Herring Gull, Common Eider, Roseate Tern, Common Tern, and Arctic Tern. Leach's Storm-petrel, which is at the southernmost extent of its nesting range in Massachusetts, is present only on two offshore islands. Stability of the nesting colonies is not solely a function of physical separation from the mainland; population management is critical, particularly at sites with populations of Roseate Terns and Common Terns, the majority of which are concentrated at very few sites. These islands also support many of rare coastal plants of conservation concern.

Seabeach Amaranth (*Amaranthus pumilus*) is listed as Historic for Massachusetts as it has not been observed and reported in Massachusetts for over 150 years. It is listed as federally Threatened under the federal Endangered Species Act. This plant was previously observed on the beaches of Martha's Vineyard and Nantucket, and still occurs on sandy barrier islands in New York and the Carolinas. It is proposed for reintroduction to federally protected lands in Massachusetts (Monomoy National Wildlife Refuge).

Table 4-22: Species of Greatest Conservation Need in Coastal Dunes, Beaches, and Small Islands

Taxon Grouping	Scientific Name	Common Name
Birds	*Ardea alba*	Great Egret
	Arenaria interpres	Ruddy Turnstone
	Calidris alba	Sanderling
	Calidris canutus	Red Knot
	Calidris pusilla	Semi-palmated Sandpiper
	Charadrius melodus	Piping Plover
	Chordeiles minor	Common Nighthawk
	Egretta thula	Snowy Egret
	Eremophila alpestris	Horned Lark
	Haematopus palliatus	American Oystercatcher
	Larus argentatus	Herring Gull
	Larus atricilla	Laughing Gull
	Larus marinus	Great Black-backed Gull
	Limnodromus griseus	Short-billed Dowitcher
	Numenius borealis	Eskimo Curlew
	Numenius phaeopus	Whimbrel
	Nycticorax nycticorax	Black-crowned Night-Heron
	Oceanodroma leucorhoa	Leach's Storm-Petrel
	Phalacrocorax auratus	Double-crested Cormorant
	Plegadis falcinellus	Glossy Ibis
	Progne subis	Purple Martin
	Riparia riparia	Bank Swallow
	Somateria mollissima	Common Eider
	Sterna dougallii	Roseate Tern
	Sterna hirundo	Common Tern
	Sterna paradisaea	Arctic Tern
	Sternula antillarum	Least Tern
	Tringa semipalmata	Willet
Beetles	*Cicindela dorsalis dorsalis*	Northeastern Beach Tiger Beetle
	Cicindela limbalis	Claybank Tiger Beetle
Lepidoptera	*Cingilia catenaria*	Chain-dotted Geometer
	Sympistis riparia	Dune Sympistis
Plants	*Amaranthus pumilus*	Seabeach Amaranth
	Aristida tuberculosa	Seabeach Needlegrass
	Corema conradii	Broom Crowberry
	Crocanthemum dumosum	Bushy Rockrose
	Juncus debilis	Weak Rush
	Lathyrus palustris	Marsh-pea
	Leymus mollis ssp. *mollis*	Sea Lyme-grass

Taxon Grouping	Scientific Name	Common Name
	Liatris novae-angliae	New England Blazing Star
	Mertensia maritima	Oysterleaf
	Opuntia humifusa	Eastern Prickly Pear
	Polygonum glaucum	Sea-beach Knotweed
	Rumex pallidus	Seabeach Dock
	Setaria parviflora	Bristly Foxtail
	Suaeda calceoliformis	American Sea-blite
	Suaeda maritima ssp. *richii*	Rich's Sea-blite

Threats to Coastal Dunes, Beaches, and Small Islands

These sandy habitats are constantly changing due to the effects of wind, waves, and salt spray. However, they are also resilient in their natural state.

IUCN Threat 1: Residential and Commercial Development
There are many areas along the Massachusetts coastline where both residential and commercial developments extend to the ocean. The Northeastern Beach Tiger Beetle and rare coastline plants (particularly Sea-beach Knotweed and Oysterleaf) have created conflicts with landowners proposing to stabilize their land to protect homes from erosion, for these species thrive on open, shifting sand habitat. Residential development in coastal areas has also threatened rare plant species that occur beyond the beaches, including New England Blazing Star and Bushy Rockrose.

Residential and commercial development increases beach recreation and trampling by beachgoers is a continual threat for rare plants and animals. Off-road vehicles often pulverize plants and animals in these habitats. Heavily used beaches are essentially devoid of any potential habitat for rare plant species, and block migration of species from one side of the beach to the other. All plants in these areas are trampled or pulled by beachgoers. In Massachusetts, Northeastern Beach Tiger Beetles have been eliminated from 98% of formerly occupied beaches by motorized off-road vehicles.

Similarly, there is high overlap between nesting habitat for resident shorebirds and seabirds (especially Least Tern, Piping Plover, and American Oystercatcher) with developed coastline and recreational beaches. Over the past few decades, consistent implementation of state rare species and wetlands regulations, along with implementation of state and federal guidelines for managing recreational use of beaches to protect terns, plovers, and their habitats, have largely been successful at allowing persistence and even increasing these species at heavily used and developed beaches. However, pressure on coastal species as a result of development in heavily-populated Massachusetts is ever-present.

Increased human activity around coastal grasslands may increase the presence of both wild mesopredators and domestic predators such as cats and dogs. Mesopredators decrease the reproductive performance of nesting seabirds and shorebirds. Impact from invasive plant species greatly increases in the proximity of development as a result of introduction to the area, either directly (e.g., landscaping) or indirectly (e.g., dumping of contaminated soil or other contaminated material).

IUCN Threat 2: Agriculture and Aquaculture
The extent to which aquaculture installations in intertidal areas affects seabird use of those areas has not been explored in Massachusetts.

IUCN Threat 3: Energy Production and Mining
Large energy-production projects of any sort are a threat to the rare species that inhabit those areas. In coastal areas, energy production from wind turbines and ocean wave power could require large supporting infrastructure, destroying habitat for many rare species. Wind-turbine installations cause mortality to birds and bats and may alter or reduce habitat for nesting or foraging. Offshore wind turbines and ocean-

wave-power facilities have been proposed for Massachusetts; as yet, none have been constructed.

Sand mining of nearshore areas could reduce foraging habitat and prey abundance for terns, sea ducks, and other birds, and also may degrade beach habitat by depleting source material that would otherwise accrete on the coastline through natural processes. Sand mining has been proposed for a few sites in Massachusetts; because of environmental concerns, no such mining has taken place at this point.

IUCN Threat 4: Transportation and Service Corridors
Regular oil barge traffic through Buzzards Bay and Cape Cod Bay remains a constant threat to Massachusetts' highest concentrations of vulnerable coastal birds. A major oil spill in Buzzards Bay in April 2003 resulted in oiling of two of the three largest Roseate Tern nesting islands in North America. This occurred at the start of the nesting season and oiling at one of the islands was severe.

IUCN Threat 5: Biological Resource Use
The harvest of horseshoe crabs has been linked to decline of the Red Knot (Niles et al. 2009). Overharvest of fish can harm seabirds that rely on them (Croxall et al. 2012).

IUCN Threat 6: Human Intrusions and Disturbance
Massachusetts' high human population density results in continual adverse impact to the coastal environment (see also IUCN Threat 1, above). Human intrusion into and disturbance of the coastal environment includes: coastal development, beach stabilization, introduction of invasive species (including domestic animals), heavy recreational beach use, damage from motorized off-road vehicles, and beach raking. These activities degrade beaches by altering natural sand transport, destroying vegetation, causing mortality of invertebrates, reducing availability of invertebrate prey to birds, disturbing foraging, nesting, and resting birds, reducing coastal waterbird nesting success, and attracting mesopredators that feed on human refuse and also prey on coastal waterbirds and invertebrates.

IUCN Threat 7: Natural System Modifications
One of the greatest threats to coastal dunes and beaches is efforts by people to stop the coast from changing, especially through artificial beach-stabilization efforts, and interference with natural stabilizing mechanisms such as beach-grass establishment. Stabilization of cliffs deprives downstream beaches of sediment supply. Jetties and groins interrupt longshore drift of sediment. The natural processes of erosion and accretion are important for maintaining suitable habitat for beach-nesting birds, including Piping Plover, Least Tern, and American Oystercatcher; for invertebrates such as the Northeastern Beach Tiger Beetle and Claybank Tiger Beetle; and for plants like Oysterleaf and Seabeach Knotweed. Trails, roads, and walkways exacerbate erosion by creating cuts and channels through dunes where wind and waves follow, further eroding dunes and over-washing interdunal areas. Vehicular traffic destroys stabilized dunes and vegetation, as well as disturbing or crushing nesting birds, invertebrates, and plants. Beach raking to remove litter and vegetation may destroy habitat for both animals and plants.

IUCN Threat 8: Invasive and Other Problematic Species
Wild and domestic animals destroy or disturb seabird and shorebird nests, causing abandonment and mortality of eggs and young. Severe or repeated predation can discourage future use of a site by nesting birds.

Sea-poppy (*Glaucium flavum*), an invasive species in Massachusetts, is a potential threat to rare plants on beaches and coastal dunes. Dense growth of Sea-poppy may shade other plants and prevent their growth, but it is not known if this species actually has a negative effect on the populations of rare plants. This plant is also highly toxic to people.

Back dunes are particularly vulnerable to invasion by exotic plants, such as Scotch Broom (*Cytisus scoparius*). The impact of exotic plants on rare native interdunal plants such as Broom Crowberry and Bushy Rockrose are not well-documented, but the potential threat is great.

On small islands where seabirds nest, weedy plant species such as mustards (*Brassica* spp.), Wild Radish (*Raphanus raphanistrum*), Common Ragweed (*Ambrosia artemisiifolia*), and smartweeds (*Polygonum spp.)* often replace plants more compatible with nesting birds, resulting in habitat degradation through rank vegetative overgrowth that limits the extent of suitable nesting habitat and reduces productivity.

Disease outbreaks (for example, Wellfleet Bay virus) and harmful marine algal blooms (for example, "red tide") may cause mortality of wildlife, especially seabirds. Disease transmission has the potential to occur rapidly where wildlife population densities are high, for instance in seabird colonies.

IUCN Threat 9: Pollution
Oil spills and other pollutants are a major threat to coastal systems. Regular oil-barge traffic through Buzzards Bay and Cape Cod Bay remains a constant threat to Massachusetts' highest concentrations of vulnerable coastal birds. A major oil spill that occurred in Buzzards Bay in April 2003 resulted in oiling of two of the three largest Roseate Tern nesting islands in North America. This occurred at the beginning of the nesting season, and oiling at one island was severe. Other oil spills have resulted in mortality of thousands of sea ducks.

Accumulation of human trash is a continual threat along the coastline, where trash washes ashore from a wide variety of sources. Trash may accumulate on top of rare shoreline plants, preventing their growth. Severe entanglement of wildlife in discarded monofilament fishing line and swallowing of hooks attached to line are common sources of injury and mortality, especially in birds. Partially inflated Mylar balloons are common beach trash items that can startle ground-nesting birds and result in nest abandonment. Deflated balloons and other trash may land on and obscure nests, resulting in egg mortality.

IUCN Threat 10: Geological Events
Geological events are not a major threat to this habitat, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Seabeach Dock, Oysterleaf, and Sea Lyme-grass are all at or near the southern extent of their geographic ranges in Massachusetts. A warmer climate may cause these species to retreat northward, extirpating them from the state.

An increase in severe-weather events such as storms will be accompanied by an increased frequency of surges, which will accelerate the rate of erosion and other coastal geological processes faster than native wildlife can adapt to such change.

Coastal dunes, beaches, and small islands may be lost, reduced in extent, or adversely modified by a rise in sea level, endangering species that depend upon these habitats.

Conservation Actions

Direct Management of Natural Resources
In coastal dunes, beaches, and small islands habitats, it is critical to allow the natural processes of continual erosion and deposition that create and maintain these habitats for a wide variety of SGCN animals and plants.

At dunes, beaches, and islands where coastal waterbirds nest, intensive annual management of human use, predators, vegetation, and disturbance is necessary to maintain viable breeding populations.

In adversely impacted coastal dunes, beaches, and small-island habitats, restoration of native vegetation is a priority. Exotic invasive *Phragmites*, Purple Loosestrife (*Lythrum salicaria*), and Gray Willow (*Salix cinerea*) are primary threats to coastal interdunal swales. There is a wide variety of other invasive plants that threaten dune systems. Important dune areas should be evaluated for the threat of invasive plants and, when possible, appropriate management action should be taken. Management of weedy, invasive plants on seabird nesting islands is a priority.

While salt spray is the primary natural process that maintains the series of mid-to-late seral natural communities associated with dunes, including Maritime Shrubland and Maritime Pitch Pine on Dunes, occasional fire has also maintained these disturbance-dependent communities, historically. Therefore, important occurrences of these communities should be evaluated with regard to species composition and structure, and a fire regime with a wide return frequency should be implemented when appropriate.

Data Collection and Analysis
Ongoing monitoring is important to inform both habitat management for coastal dunes, beaches, and small islands, as well as population management of resident

and migratory species of conservation concern. Such data collection and analysis should include:

- Annual census and productivity assessment for nesting Piping Plovers, American Oystercatchers, terns, skimmers, and Laughing Gulls, as well as the Northeastern Beach Tiger Beetle, to determine population trends and limiting factors.
- Periodic survey of coastal wading-bird, gull, and cormorant colonies to determine population trends. Novel research methods should be investigated to enhance efficiency and quality of surveys (for example, aerial photography). Productivity should be assessed at select sites. Causes of population decline should be investigated.
- Periodic survey of migrating and staging seabirds and shorebirds to determine site usage and threats.
- Research on the natural history and ecology of poorly-understood animals and plants of coastal dunes, beaches, and small islands.
- Investigation of the temporal and spatial use patterns of the coastal marine environment by birds, especially terns and Piping Plovers.
- Research on factors that may have negative impacts on resident and migratory coastal birds in their breeding, foraging, staging, and wintering habitats. These factors may include disturbance, disease, invasive species, predation, habitat degradation, habitat modification, and miscellaneous human activities.
- Investigation of interactions between fishing, aquaculture, and seabird abundance and productivity.
- Extensive searches for any naturally occurring populations of Seabeach Amaranth. If it is relocated or successfully reintroduced to the state, it will be listed on the state's list of rare species.
- Documentation of the impact of exotic invasive plant species such as Sea-poppy and Scotch Broom on native plant and animal species of conservation concern.
- Documentation of the impact of fire exclusion on maritime shrublands and woodlands.
- Continuation and expansion of nightjar surveys in dune habitats.

Education and Outreach
In order to promote conditions that benefit coastal dunes, beaches, and small islands, and the animals and plants that inhabit them, it is important to provide technical assistance to landowners and beach managers responsible for rare and vulnerable species on their properties.

Harvest and Trade Management
Responsible management of commercial fisheries is necessary to protect stocks for both people and wildlife. Further research is needed on the potential effects of coastal and near-shore natural resource harvest on animals and plants inhabiting these areas.

Land and Water Rights Acquisition and Protection
In Massachusetts, acquisition of coastal land is generally cost-prohibitive, particularly with regard to large acquisitions. Therefore, it is important to use existing laws and regulations to protect coastal dunes, beaches, and small islands, and the animals and plants that inhabit them (see Law Enforcement below). In particular, siting and permitting of aquaculture, wind-energy facilities, and large-scale projects should take into account the importance of affected areas for seabirds, shorebirds, and wading birds, in particular, as well as any other animals and plants of conservation concern.

Law Enforcement
Increase law enforcement capacity on the coast to protect coastal dunes, beaches, and islands and the species that inhabit them.

Law and Policy
Massachusetts has three major, complementary, environmental protection laws: the Massachusetts Environmental Policy Act (MEPA), the Wetlands Protection Act (WPA), and the Massachusetts Endangered Species Act (MESA). The MESA protects species that are listed as Endangered, Threatened, or of Special Concern in Massachusetts, all of which are also SGCN species. The MESA is administered by the Massachusetts Division of Fisheries & Wildlife, which, through regulatory implementation, annually reviews over 2,000 projects or activities in known habitats of state-listed species.

Regulatory review under the MESA is one of the most effective ways to avoid, minimize, and/or mitigate threats to state-listed and SGCN species in coastal dunes, beaches, and small-island habitats. Such threats that are discussed above as they apply to these habitats and the species that depend on them include: (1) residential and commercial development, including energy-production facilities; (2) structural changes, including beach, dune, bluff, and cliff stabilization, as well as the building of roads, trails, and walkways; (3) sand mining; (4) oil spills; (5) beach recreation, especially off-road vehicles and human intrusion into dune habitat and designated seabird and shorebird nesting habitat; (6) wild and domestic predators of nesting shorebirds and seabirds; (7) adverse habitat management practices; and (8) invasive plants.

Incentivize management practices that benefit beach species and their habitats.

Stronger legislation is needed to minimize the probability of a catastrophic oil spill, and increase penalties in the case of such an event.

Planning

Develop detailed conservation and recovery plans for SGCN associated with coastal dunes, beaches, and small islands. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Oil spill response guidelines need revision and improvement. In particular, a pre-oil-spill response plan is necessary so that critical coastal waterbird nesting sites are preidentified and prioritized in response actions. Further development of methods to physically shield the most critical sites is needed.

Species Reintroduction and Stocking

The Northeastern Beach Tiger Beetle reintroduction at Monomoy National Wildlife Refuge has been very successful. Additional vehicle-free beaches should be identified and evaluated for suitability as additional restoration sites.

Evaluate islands for suitability as seabird nesting sites and manage a network of such sites to buffer populations from disturbance.

Seabeach Amaranth (*Amaranthus pumilus*) is proposed for reintroduction to federally protected lands in Massachusetts (Monomoy National Wildlife Refuge). The reintroduction will be conducted by the U.S. Fish and Wildlife Service.

Grasslands

Habitat Description

In Massachusetts, grasslands are disturbance-dependent and often anthropogenic (Brown 1985). All areas of the state receive more than enough annual precipitation for woody vegetation to dominate, the only exception being relatively small areas of excessively sandy or rocky soils that do not retain water. Everywhere else, some form of disturbance, either natural or anthropogenic, is needed to exclude woody vegetation and allow the persistence of grassland habitat.

In Massachusetts prior to European settlement, nonanthropogenic native grasslands were likely restricted to relatively small areas along rivers, adjacent to wetlands periodically flooded by beaver, and along the coast as a result of wind and salt spray. However, known Native American settlement patterns and land-use practices prior to European colonization suggest that open habitats with a significant grassy component would have occurred throughout the state. Native Americans burned both woodlands and shrublands, particularly those occurring on dry, sandy soils, in order to improve conditions for travelling and hunting (Brown 1985). Fire not only opened habitat for ease of travel and improved lines of sight for hunting, but also improved habitat conditions for wildlife, including species hunted by Native Americans. For example, for several years after a fire, lowbush blueberries respond with rapid growth and prolific berry production. This attracts a wide variety of mammals and birds that feed on blueberries.

In Massachusetts, from colonial settlement through the mid-1800s, land was extensively cleared for various agricultural activities (Foster and Aber 2004). This resulted in a dramatic decrease in forested land and a dramatic increase in grassland habitat in the form of grazing pastures, hay fields, and margins of crop fields. Agriculture has greatly declined in the state since the mid-1800s, and most historical agricultural lands have become reforested (Brown 1985, Foster and Aber 2004). Currently, agriculture occurs at a much smaller scale than at its historical peak, and continues to decline. Pastures, hay fields, margins of crop fields, and other anthropogenic agricultural grasslands are now relatively rare in Massachusetts, particularly in the more urban and suburban eastern half of the state.

Nevertheless, a wide variety of grasslands persist in Massachusetts, and many grasslands overlap with, or intergrade into, other habitats discussed in this State Wildlife Action Plan. For example, within Pitch Pine/Scrub Oak communities, openings of dry, native grassland often occur due to either natural (e.g., frost, fire) or anthropogenic disturbance. Other examples include dry "dune grass grasslands" on coastal dunes; dry, grassy shrublands along the coast, kept free of tall woody vegetation by wind and salt spray; wet, grassy peatlands; and wet meadows kept open by periodic flooding (often a result of beaver activity) or anthropogenic disturbance.

Different types of grasslands may be described by classifying them according to various characteristics, including edaphic characteristics, disturbance history, and species composition. These characteristics are not discrete, grading into each other in much the same way grasslands grade into other habitat types. Nevertheless, it is often useful to describe a grassland as dry or wet, natural or anthropogenic, predominantly warm-season or cool-season grasses, and/or predominantly native species or introduced species. Grasslands exhibiting particular combinations of these criteria are more common than others in Massachusetts, and are discussed separately below.

Abandoned agricultural land

Abandoned agricultural land, including former pastures, hay fields, and crop fields, provide ephemeral grassland habitat. Most abandoned pastures and crop fields occur on mesic soils, and are dominated by introduced, cool-season grasses. As a result, these grasslands typically only provide habitat for more common and widespread species of wildlife; however, some of these species are important game animals. One SGCN found in such grasslands is the American Woodcock, for which recently-abandoned pastures provide ideal nesting habitat. In contrast, former pastures or fields on rocky uplands or other soils that are dry or nutrient-poor may consist of grasslands dominated by native warm-season grasses. Such grasslands provide habitat for a greater diversity of native plants and animals, including some rare species that may be state-listed or SGCN. In the absence of active management, all abandoned agricultural grasslands become increasingly overgrown by woody vegetation. The rate at which this proceeds depends on characteristics of the grassland, with dry, native, warm-season pastures and fields typically persisting longer than mesic areas with introduced, cool-season grasses. As abandoned agricultural grasslands become increasingly overgrown, suitability for grassland species diminishes, and eventually the habitat disappears altogether.

Active agricultural land

Active agricultural land, including pastures, hay fields, and margins of crop fields, usually occur on mesic soils, and are typically planted with introduced, cool-season grasses. These grasslands are maintained by grazing livestock, harvesting of hay, or other mechanical cutting. The characteristics of grasslands in active agricultural use limit their value as wildlife habitat, and these grasslands rarely provide habitat for species of conservation concern.

Airports and military bases

In Massachusetts, some grasslands located at airports and military bases provide habitat for state-listed species and SGCN. Of particular importance are airfields that are located on dry, sandy soils, and therefore support native, warm-season grasses and native forbs. Airfield grasslands with these characteristics that consequently provide habitat for concentrations of state-listed species and SGCN include Westover Air Reserve Base in Chicopee, Turners Falls Airport in Montague, Barnes Municipal Airport in Westfield, Plymouth Airport, Otis Air Force Base at the Massachusetts Military Reservation on Cape Cod, Martha's Vineyard Airport, and Nantucket Memorial Airport. On the mainland, airports and military bases provide the only grasslands that are large enough to support breeding populations of rare grassland-obligate birds such as the Upland Sandpiper and Grasshopper Sparrow.

Dry native grasslands

Dry native grasslands dominated by Little Bluestem (*Schizachyrium scoparium*) and other warm-season grasses occur throughout Massachusetts in various sizes and configurations. Historical accounts describe open areas that were probably composed of grasses, forbs, and heath, as well as shrub and tree saplings and resprouts. Currently, the largest and highest quality dry, native grassland and grassland/shrubland habitats occur on the islands of Martha's Vineyard and Nantucket, on lands that were historically plowed or grazed. At these sites, the effects of coastal wind and salt spray delay succession to shrubland, woodland, and forest. A large number of state-listed species, SGCN, and other grassland species thrive in these habitats. On Cape Cod, Francis Crane Wildlife

Management Area (WMA) includes a 200-acre dry native grassland at the site of a former airport, which has been actively restored, expanded, and managed by the Division of Fisheries and Wildlife for the past 18 years.

Savannas

In Massachusetts, based on historical accounts, research including pollen and charcoal studies, and research on the effects of fire, homogeneous grasslands would not likely have resulted solely as a result of fire. A more likely historical landscape in fire-influenced areas would have been structurally and compositionally complex, and would not have consisted of homogeneous grassland, shrubland, or forest. Instead, fire would likely have resulted in a shifting mosaic of grasses and forbs, shrubs, and trees, typically with canopy cover of less than 60 percent. Such savanna and open oak woodland habitats are currently very rare on the Massachusetts landscape. Where they do occur, these habitats support a number of state-listed species, SGCN, and other grassland species, particularly birds, moths and butterflies, and plants.

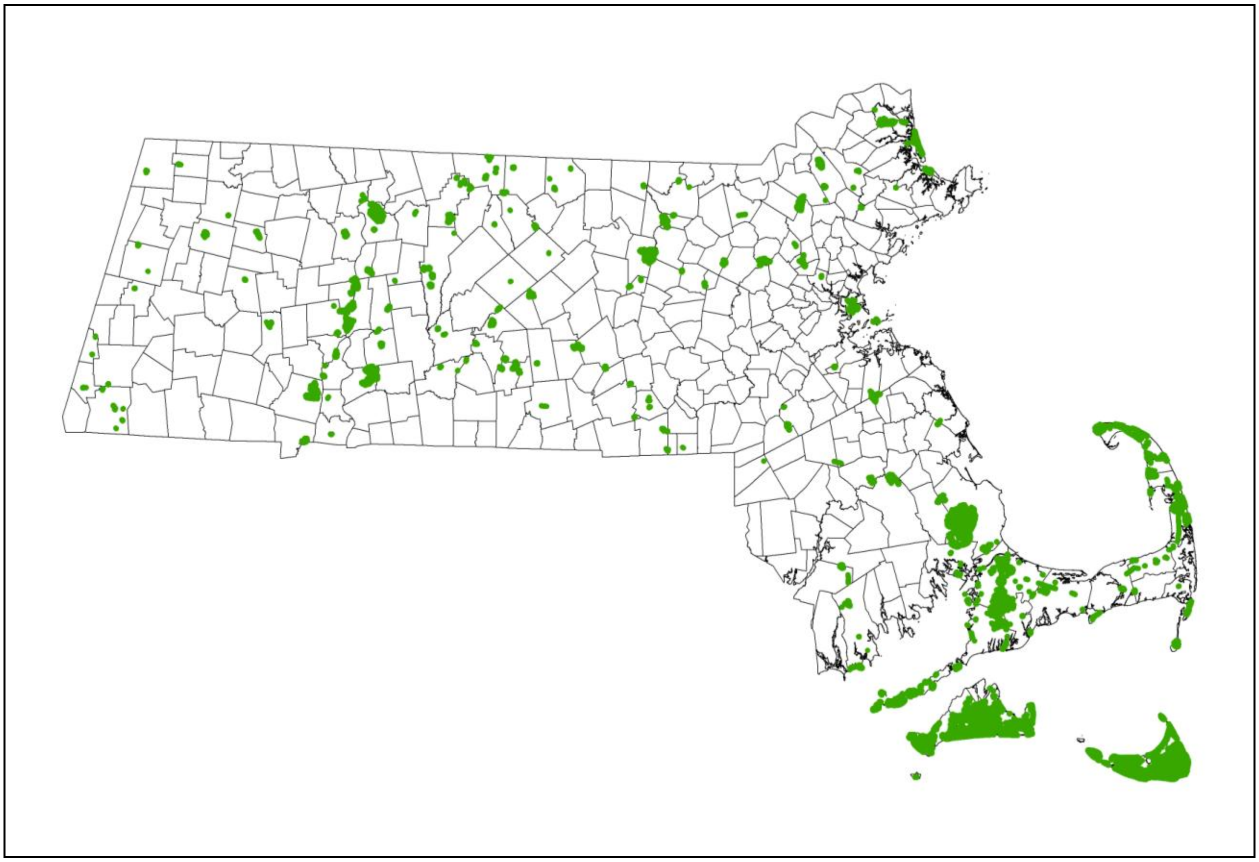


Figure 4-28: Locations of Major Grasslands in Massachusetts.

Species of Greatest Conservation Need in Grasslands

Seventy-one SGCN are assigned to the Grasslands habitat (Table 4-23).

Seven species of state-listed and SGCN birds in Massachusetts are highly dependent on grassland habitat for nesting, for overwintering, or during migration. Most of the nesting sites for these species are near the coast of the mainland or on the larger offshore islands. However, the Upland Sandpiper, Vesper Sparrow, and Grasshopper Sparrow are also found in scattered inland locations, mostly grasslands at airports (e.g., Westover Air Reserve Base, Plymouth Airport). Five other SGCN birds that are uncommon and declining in the state are also associated with grassland habitats, including the Eastern Meadowlark, Eastern Whip-poor-will, Northern Bobwhite, American Kestrel, and American Woodcock. The latter four species prefer habitat that is less open and more structurally complex, with shrubs and young trees distributed in scattered patches throughout the grassland.

The Southern Bog Lemming prefers wet grassland habitat, often within or bordering bogs and other wetlands, while the Eastern Hog-nosed Snake prefers dry grassland habitat on sandy soil. However, the specific habitat needs of both of these species need further study.

The American Burying Beetle is listed as Endangered under both the federal Endangered Species Act and the MESA, as well as being a SGCN species. In Massachusetts, the American Burying Beetle is restricted to Nantucket, where a reintroduced population currently exists at apparently healthy population levels (Mckenna-Foster et al. 2010). The Purple Tiger Beetle is also faring best on the offshore islands, but a few scattered mainland populations remain, mostly in the southeastern part of the state. Both of these species are strongly associated with grassland and savanna habitats.

Nine state-listed and SGCN moths and butterflies are associated with grassland habitats in Massachusetts. Dry, native sandplain grassland is the preferred habitat for many of these. For example, the Frosted Elfin, Persius Duskywing, and Southern Ptichodis inhabit grassy openings within Pitch Pine/Scrub Oak communities. The Coastal Heathland Cutworm is found in coastal dunes and heathlands. Others, such as the Scrub Euchlaena and Sandplain Heterocampa, prefer more structurally complex savanna habitat.

In Massachusetts, grasslands are the preferred habitat for 38 state-listed and SGCN plants. Species such as Sandplain Gerardia, Purple Needlegrass, Broom Crowberry, Bushy Rockrose, Commons' and Rough Panic-grass, Sandplain and Stiff Yellow Flax, Bayard's Adder's Mouth, and Broad Tinker's-weed only grow in grasslands on dry, sandy soil located in eastern Massachusetts near the coast, including on Cape Cod and the offshore islands. Other grassland plants occur on glacial outwash plains and similar acid-soil habitats in the central part of the state, including Upright False Bindweed, Midland Sedge, Houghton's Flatsedge, Wild Senna, Wild Pink, and Sand Violet. Still others are only found in grasslands in western Massachusetts, particularly on calcareous soils, including Culver's-root, Narrow-leaved Vervain, Willow Aster, and Gattinger's Panic-grass. Eight state-listed and SGCN grassland plants each have only one known population in the state. One grassland species, the New England Blazing Star, is endemic to New England and New York.

Table 4-23: Species of Greatest Conservation Need in Grasslands

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Heterodon platirhinos*	Eastern Hog-nosed Snake
	Opheodrys vernalis	Smooth Greensnake
Birds	*Ammodramus savannarum*	Grasshopper Sparrow
	Asio flammeus	Short-eared Owl
	Asio otus	Long-eared Owl
	Bartramia longicauda	Upland Sandpiper
	Chaetura pelagica	Chimney Swift
	Circus cyaneus	Northern Harrier
	Colinus virginianus	Northern Bobwhite
	Dolichonyx oryzivorus	Bobolink
	Eremophila alpestris	Horned Lark
	Falco sparverius	American Kestrel
	Pooecetes gramineus	Vesper Sparrow
	Progne subis	Purple Martin
	Scolopax minor	American Woodcock
	Sturnella magna	Eastern Meadowlark
	Tyto alba	Barn Owl
Mammals	*Synaptomys cooperi*	Southern Bog Lemming
Beetles	*Cicindela purpurea*	Purple Tiger Beetle
	Nicrophorus americanus	American Burying Beetle
Lepidoptera	*Abagrotis nefascia*	Coastal Heathland Cutworm
	Callophrys irus	Frosted Elfin
	Cycnia inopinatus	Unexpected Cycnia
	Erynnis persius persius	Persius Duskywing
	Euchlaena madusaria	Scrub Euchlaena
	Dargida rubripennis	The Pink-streak
	Grammia phyllira	Phyllira Tiger Moth
	Heterocampa varia	Sandplain Heterocampa
	Ptichodis bistrigata	Southern Ptichodis
Bees	*Anthophora walshii*	Walsh's Anthophora
	Epeoloides pilosula	Macropis Cuckoo Bee
	Macropis ciliata	Ciliary Oil-collecting Bee
	Macropis nuda	Naked Oil-collecting Bee
	Macropis patellata	Patellar Oil-collecting Bee
Plants	*Agalinis acuta*	Sandplain Gerardia
	Aristida purpurascens	Purple Needlegrass
	Asclepias purpurascens	Purple Milkweed
	Calystegia spithamaea	Upright False Bindweed
	Carex bushii	Bush's Sedge
	Carex mesochorea	Midland Sedge
	Carex polymorpha	Variable Sedge
	Corema conradii	Broom Crowberry
	Crataegus bicknellii	Bicknell's Hawthorn
	Crocanthemum dumosum	Bushy Rockrose
	Cyperus houghtonii	Houghton's Flatsedge
	Dichanthelium ovale ssp. *pseudopubescens*	Commons' Panic-grass
	Dichanthelium scabriusculum	Rough Panic-grass
	Eleocharis microcarpa var. *filiculmis*	Tiny-fruited Spike-sedge
	Gamochaeta purpurea	Purple Cudweed
	Gentiana linearis	Narrow-leaved Gentian
	Hypericum hypericoides ssp. *multicaule*	St. Andrew's Cross
	Lathyrus palustris	Marsh-pea
	Lechea pulchella var. *moniliformis*	Beaded Pinweed

Taxon Grouping	Scientific Name	Common Name
	Liatris novae-angliae	New England Blazing Star
	Linum intercursum	Sandplain Flax
	Linum medium var. *texanum*	Stiff Yellow Flax
	Lupinus perennis	Wild Lupine
	Malaxis bayardii	Bayard's Adder's Mouth
	Nabalus serpentarius	Lion's Foot
	Panicum philadelphicum ssp. *gattingeri*	Gattinger's Panic-grass
	Scleria pauciflora	Papillose Nut-sedge
	Scleria triglomerata	Tall Nut-sedge
	Senna hebecarpa	Wild Senna
	Silene caroliana ssp. *pensylvanica*	Wild Pink
	Sisyrinchium fuscatum	Sandplain Blue-eyed Grass
	Spiranthes vernalis	Grass-leaved Ladies'-tresses
	Symphyotrichum concolor	Eastern Silvery Aster
	Symphyotrichum praealtum	Willow Aster
	Triosteum perfoliatum	Broad Tinker's-weed
	Viola adunca	Sand Violet
	Veronicastrum virginicum	Culver's-root
	Verbena simplex	Narrow-leaved Vervain

Threats to Grasslands

IUCN Threat 1: Residential and Commercial Development
Loss of grassland to residential and commercial development is a major threat to state-listed species and SGCN. Both historical and current developments are often sited on grasslands, as these habitats typically occur on flat, easily-developed topography. In particular, dry, native sandplain grassland often occurs in coastal locations that are very desirable for development; these same areas often overlay aquifers with an abundance of easily extracted groundwater.

Grassland habitat that is not lost outright to development may nevertheless become proximal to developed areas, which brings an increase in human activity. This may include an increased abundance of mesopredators and domestic predators (cats and dogs), posing a major threat to birds that nest in grasslands. Impacts from invasive plants increase in proximity to development, either directly (e.g., landscaping) or indirectly (e.g., introduction of contaminated soil or dumping of contaminated materials). Development often fragments grassland, reducing the quality of remaining habitat patches, especially for grassland birds and other area-sensitive species. Furthermore, the use of prescribed fire as a grassland habitat management tool becomes difficult as the landscape becomes increasingly fragmented by development.

IUCN Threat 2: Agriculture and Aquaculture
Some grassland birds, for example the Bobolink and Eastern Meadowlark, rely on hayfields as nesting habitat in Massachusetts. Incompatible haying practices, such as mowing during the breeding season, often result in hayfields becoming a population sink for these species. Similarly, the Vesper Sparrow relies heavily on large agricultural fields planted with row crops, especially in the Connecticut River Valley, and nesting attempts are often destroyed by incompatible agricultural practices during the breeding season.

IUCN Threat 3: Energy Production and Mining
Because grassland habitats often occur on flat topography, these areas are well-suited for solar installations, which may threaten grassland species, especially area-sensitive grassland birds. Solar installations typically require removal of vegetation around solar panels, making the installation footprint uninhabitable for most species, and furthermore presenting the threat of pollution from herbicide overuse.

IUCN Threat 4: Transportation and Service Corridors
In Massachusetts, airports provide important grassland habitat, particularly for grassland birds, moths and butterflies, and plants. Many state-listed species and SGCN rely on dry, native sandplain grassland habitat located at airports in the Connecticut River Valley or in the southeastern part of the state. Airfield maintenance, in particular mowing that is too frequent or too short, may conflict with nesting of grassland birds or the life cycles of grassland moths, butterflies, and plants; as a result, these habitats may become population sinks.

IUCN Threat 5: Biological Resource Use
While agricultural haying of grasslands maintains these areas as grasslands, the haying equipment also can destroy the nests, eggs, or fledglings of ground-nesting birds, run over and kill snakes and turtles (especially Wood Turtles, which prefer feeding in fields), prevent seed set for rare grassland plants, and disrupt life cycles of rare grassland invertebrates. Changes in mowing regimes over the past century, including earlier and more frequent cutting, exacerbate the deleterious impacts on grassland SGCN.

IUCN Threat 6: Human Intrusions and Disturbance
The use of off-road vehicles (ORVs) at grassland sites may damage habitat, cause direct mortality of animals and plants, and disturb animals to the point that the habitat becomes unsuitable. One example is the Southwick WMA, where intensive ORV traffic has severely damaged habitat that once supported the state-listed/SGCN Grasshopper Sparrow. This species no longer nests in the ORV-damaged portion of the WMA. Efforts are underway to halt this illegal intrusion so that the Grasshopper Sparrow can use the habitat to its former extent.

IUCN Threat 7: Natural System Modifications
Loss of dry, native sandplain-grassland habitat to woody vegetation as a result of fire exclusion is the primary threat on otherwise protected conservation lands.

IUCN Threat 8: Invasive and Other Problematic Species, Genes, and Diseases
In Massachusetts, dry, native sandplain grasslands are threatened by invasion by Spotted Knapweed (*Centaurea maculosa*), Cypress Spurge (*Euphorbia cyparissias*), Pale Swallowwort (*Cynanchum rossicum*), Black Swallowwort (*Cynanchum louiseae*), and Feathertop Grass (*Calamagrostis epigejos*). In other types of grasslands, Reed Canary Grass (*Phalaris arundinacea*) and a variety of woody invasives pose a serious threat.

Overly abundant deer excessively browse vegetation, including some plants of conservation concern. Overbrowsing by deer is also a threat to Lepidoptera and other animals that depend on particular plants for food, for example the Frosted Elfin and Persius Duskywing butterflies.

The American Burying Beetle has disappeared from more than 90% of its historical range (Ratcliffe 1996). The cause(s) of this decline are poorly understood, but the pattern of extirpation suggests that a pathogen such as a virus or bacteria may be responsible.

IUCN Threat 9: Pollution
Pollution is not a major threat to grasslands in Massachusetts.

IUCN Threat 10: Geological Events
Geological events are not a major threat to grasslands in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
According to climate-change projections, severe weather events (e.g., summer drought) are predicted to increase in severity, frequency, and duration. However, relative to most other habitats, healthy and diverse native grasslands may be more resilient to drought and other severe weather events.

Conservation Actions

Direct Management of Natural Resources
The greatest management needs for grassland habitats in Massachusetts are prescribed fire (sometimes in combination with mechanical cutting) and control of invasive exotic vegetation. In combination, these two management activities promote native grassland habitats (in terms of both species composition and

structure), which in turn promote the persistence of animal species that depend on native grassland plants.

Invasive-plant species may be dealt with before they become established by developing and implementing protocols to control potential vectors (contaminated soil, landscaping, equipment, etc.), and by addressing pioneering invasive populations through early detection—rapid response programs. Such proactive measures are key to maintaining important grassland habitats and should be pursued whenever possible.

Restoration and management of grasslands is a high priority, particularly on protected lands. Areas currently dominated by nonnative cool-season grasses and other invasive plants should be converted to grasslands dominated by native grasses, forbs, and heath by mechanical cutting, prescribed fire, and seeding. At some existing grassland sites expansion is desirable, and may be achieved by converting adjacent areas dominated by woody vegetation. The DFW is doing this at Bolton Flats WMA, Francis Crane WMA, Penikese Island, and Southwick WMA.

Continued implementation, and additional development, of grassland management agreements with airports and military bases is of high importance for conservation of grassland animals and plants in Massachusetts.

The U.S. Department of Agriculture's NRCS and the DFW have partnered for 6 years in a Farm Bill-funded program to provide technical assistance to private landowners on habitat management projects designed to benefit SGCN. As part of this partnership, projects have involved enhancing or maintaining habitat through delayed mowing for grassland-nesting birds or turtles and through installation of American Kestrel nest boxes. NRCS also offers reimbursement for prescribed burning to manage grassland habitat and other fire-adapted plant communities. This partnership should continue, with continued emphasis on restoration and management of grasslands and shrublands.

Data Collection and Analysis
In Massachusetts, some grassland species are both undersurveyed and poorly understood with regard to their natural history. Examples include Southern Bog Lemming and Eastern Hog-nosed Snake. These and other data-deficient species should be priorities for future surveys and research.

Annual, ongoing, statewide grassland-bird surveys, conducted in conjunction with cooperators, should be continued. Similarly, working with airports and military bases to survey and conserve populations of SGCN birds and other grassland species is a priority. Currently, all recent breeding locations for the Grasshopper Sparrow and Upland Sandpiper have been identified, and the most important breeding sites are priorities for both surveys and conservation actions. Another ongoing action that should continue is the deployment and monitoring of nesting boxes for the American Kestrel.

Annual, ongoing, statewide grassland-plant surveys, conducted in conjunction with cooperators, should be continued. For example, populations of some SGCN grassland plants were newly discovered within the past year.

Education and Outreach
The DFW is currently working with conservation organizations, farmers, and airport and landfill managers toward more compatible land-use practices that promote grassland-habitat conservation for birds and other state-listed species and SGCN. An important action that should be continued and expanded upon is educating and working with local planning boards and conservation commissions to implement native grassland restoration and conservation plans. For example, post-closure restoration and management plans for sand and gravel extraction sites and landfills should target development of warm-season grassland, as opposed to more typical landscaping with turf grass and trees.

Land and Water Rights Acquisition and Protection
Protection and management of grasslands supporting populations of SGCN animals and plants is an ongoing priority. Acquisition of the few large remaining inland sandplain-grassland habitats is desirable, when and if they become available (e.g., after closure of an airport). Similarly, lands that previously consisted of grassland habitat, but have become forested through fire exclusion or other factors, should be acquired and restored to grassland.

Law Enforcement
Massachusetts has three major, complementary environmental protection laws: the Massachusetts Environmental Policy Act (MEPA), the Wetlands Protection Act (WPA), and the Massachusetts Endangered Species Act (MESA). The MESA protects

species that are listed as Endangered, Threatened, or of Special Concern in Massachusetts, all of which are also SGCN species. The MESA is administered by the DFW, which, through regulatory implementation, annually reviews over 2,000 projects or activities in known habitats of state-listed species. Regulatory review under the MESA is one of the most effective ways to avoid, minimize, and/or mitigate threats to state-listed and SGCN species in grassland habitats.

A lack of enforcement on lands where off-road vehicle (ORV) use is prohibited has resulted in considerable and ongoing damage, particularly to grassland habitats on sandy, easily eroded soils. Expanded enforcement of ORV exclusion is greatly needed in these areas.

Planning

Develop detailed conservation and recovery plans for SGCN associated with grasslands. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Because the DFW has direct control of Wildlife Management Areas (conservation lands under its own purview), implementation of conservation actions as described in the State Wildlife Action Plan is straightforward. However, other state agencies, local municipalities, and private organizations have their own procedures for conservation planning and implementation. Because the Massachusetts DCR controls by far the largest acreage of conservation lands in the state, including all state parks and state forests, it is important that the DCR incorporate the State Wildlife Action Plan in its own conservation planning and implementation. The DCR has a challenging mandate of balancing natural resource management with a wide variety of recreational uses of state land. Therefore, it is especially important that conservation planning by the DCR consider the potential threats posed by various recreational activities on lands under its purview.

The DFW, in cooperation with the Trustees of Reservations, the Nature Conservancy, and Mass Audubon, has recently developed "An Action Plan for the Conservation of State-listed Obligate Grassland Birds in Massachusetts," available at http://www.mass.gov/eea/docs/dfg/nhesp/species-and-conservation/grassland-bird-plan-final.pdf.

There is a need to develop and implement a conservation plan for Northern Harriers breeding in Massachusetts.

Species Reintroduction and Stocking

In Massachusetts, the American Burying Beetle is restricted to Nantucket, where an ongoing reintroduction and monitoring project by the U.S. Fish & Wildlife Service and cooperators appears to have succeeded, as the reintroduced population is currently both healthy and increasing (Mckenna-Foster et al. 2010).

Various managed-grassland habitats should be evaluated for their potential to support reintroduced populations of New England Blazing Star, Wild Lupine, Wild Pink, and other SGCN plants.

Young Forests and Shrublands

Habitat Description

Collectively, young forests and shrublands are referred to as *thicket* habitats (Litvaitis 2003), and provide important resources for several wildlife species of conservation concern. Young-forest habitats are typically dominated by rapidly growing trees and shrubs, and generally occur when a mature forest canopy is disrupted, allowing sunlight to stimulate the growth of herbaceous and woody vegetation on the forest floor. Shrublands are defined here as relatively ephemeral, upland habitats that are dominated by low woody vegetation (generally less than 3 m tall), with varying amounts of herbaceous vegetation and sparse tree cover. Shrublands primarily include abandoned-field sites and powerline corridors that would ultimately revert to forest absent some human or natural disturbance (e.g., mowing or burning), and abandoned beaver flowages along forested stream courses, which typically succeed from wet meadow to drier herb/shrub habitat, and eventually revert to forest in the decades following abandonment.

Enduring shrubland habitats also occur, and include both Pitch Pine/Scrub Oak communities on relatively dry upland sites as well as shrub-dominated wetland communities (generally referred to as shrub swamps). These enduring shrublands provide unique habitats and support particular wildlife species of conservation concern, and so are treated separately in this report.

While several wildlife species use both young forest and shrubland (Litvaitis 2003), there are important differences in plant species composition and structure (Lorimer 2001) that result in some species of plants (Latham 2003) and animals (Wagner et al. 2003) occurring in one or the other; use of young-forest and shrubland habitats can also vary within a particular species' lifetime. The woody vegetation in young forest is often dominated by regenerating stands of late-successional species that are present as advanced reproduction or seed at the time of a canopy disturbance. Shrublands tend to be dominated by pioneer species whose seed can travel substantial distances (Lorimer 2001). The distinction between young-forest habitat dominated by late-successional species and shrublands dominated by pioneer species has received little attention from researchers, but may prove to be a key consideration in regional conservation planning (Askins 2001). Absent disturbance, the thicket habitats discussed here eventually succeed to mature forest.

Preserving biodiversity in temperate forest requires the maintenance of all successional stages (Franklin 1988), and managers should recognize the role of disturbance in maintaining biodiversity (DeGraaf and Miller 1996). Forest managers need to provide a range of habitats at temporal and spatial scales that will support viable populations of all native wildlife species, and this task must be accomplished in a landscape being developed for human use that does not resemble any previous historical condition. While it is instructive to examine the historical range of variability associated with natural-disturbance regimes (see Thompson and DeGraaf 2001), managers should not seek to reestablish conditions from a previous time (e.g., prior to European settlement), but rather should seek to secure a range of conditions in today's landscape that will support viable populations of native wildlife species (DeGraaf and Yamasaki 2003).

Young Forests

Young forest constitutes the first of four developmental stages of forest growth, and is technically referred to as *stand initiation* (Oliver and Larson 1996). The stand initiation stage is characterized by high stem densities (e.g., 1,000 to more than 10,000 stems per acre) and is relatively ephemeral, generally lasting about 10 years or until a young-tree canopy is formed, typically causing herbaceous and woody vegetation on the forest floor to die back. The competition for sunlight within a young-forest canopy typically results in a rapid decline in stem density during the stem-exclusion stage. Canopy gaps form as the result of stem exclusion, which facilitates plant growth on the forest floor during the understory reinitiation stage. Over time, an uneven-aged forest is formed and stands eventually enter the old-growth stage (Oliver and Larson 1996).

During the stand-initiation stage, the flush of woody and herbaceous vegetation on the forest floor provides food (e.g., berries, browse, and insects) and cover (e.g., shrubs, tree seedlings, and slash) resources for wildlife that is generally lacking in older forest. Wildlife species that prefer early-successional habitats have been perceived as habitat generalists (see Foster and Motzkin 2003), but in fact, many wildlife species associated with young forests are habitat specialists with specific vegetation structure or area requirements, such as the New England Cottontail and Chestnut-sided Warbler (DeGraaf and Yamasaki 2003). Relatively large (greater than 25 acre) patches of early-successional habitat may be necessary to maintain viable populations of mammals associated with young forest (Litvaitis 2001).

In addition, Hunter et al. (2001) note that early-successional habitats are important for wildlife species generally associated with mature forests. Examples include fledgling and molting adult Wood Thrushes (*Hylocichla mustelina*), whichmove from mature forest to patches of disturbed habitat that may be critical for food and cover resources not typically found near nesting sites.

Young forest established by clearcutting can temporarily reduce amphibian numbers (Pough et al. 1987), including the terrestrial-breeding Redback Salamander (*Plethodon cinereus*; DeGraaf and Yamasaki 1992 and 2002), the wetland-breeding Wood Frog (*Rana sylvatica*), and mole salamanders (*Ambystoma* spp.; deMaynadier and Hunter 1998), which require a moist environment and are not especially mobile. However, a shaded canopy is usually restored within 10 years. Redback Salamander numbers typically recover to pre-cut levels within 30 years (DeGraaf and Yamasaki 2002), and there is generally no difference in numbers of salamanders in 60-year-old second-growth forest vs. old-growth forest (Pough et al. 1987). Maintaining sustainable populations of amphibians can be compatible with timber harvesting (deMaynadier and Hunter 1995, Brooks 1999).

Generally, a minority of forest area is in an early-successional stage at any given point in time, so the many habitat benefits of young forest can be realized without any substantial threat to populations of mature-forest species. Overall, young forests support a great diversity of wildlife species and are a critical component of wildlife habitat at the landscape level (DeGraaf and Yamasaki 2001, 2003).

Mature-forest canopies in New England have historically been disrupted by various natural disturbance events, including wind (e.g., down-bursts, tornadoes, or hurricanes), fire (e.g., lightning strikes and intentional spring fires set by native Americans), flooding (e.g., beaver impoundments and spring floods along major rivers and streams), and pathogens (e.g., insect infestations) (see DeGraaf and Miller 1996, pp. 6-10 for review). Wind disturbances have occurred historically throughout Massachusetts, with hurricanes being more prominent in eastern Massachusetts, and downbursts and tornadoes more prevalent in western Massachusetts. Pathogens most likely had sporadic historical impact throughout the state. Fire was historically more common in the eastern part of the state and in the major river valleys. Beaver flooding occurred throughout the state until beaver were extirpated from nearly all of Massachusetts by 1700 (Foster et al. 2002). After beaver were reestablished during the 20^{th} century, limited beaver flooding now occurs in all but the southeastern part of the state.

Historical return intervals for canopy-replacing wind- and fire-disturbance events vary across Massachusetts, and are generally highest in the pitch pine-oak barrens of coastal and eastern Massachusetts (40-150 years between severe fires and/or hurricanes), followed by oak-hickory forests (85-380 years between fires and/or wind events), northern hardwood forest (500-1,500 years between wind events and occasional fires), and spruce-northern hardwood forest (230-545 years between wind, insect, and/or fire events; Lorimer and White 2003). These disturbance intervals indicate that 10-31% of pitch pine-oak barrens naturally occur in early-successional (less than or equal to 15 years old) forest, compared to 3-40% of oak forests, 1-3% of northern hardwood forests, and 2-7% of spruce-northern hardwood forest (Lorimer and White 2003).

Patch sizes for individual wind and fire disturbances appear to range from less than 1 acre to a few thousand acres, with the majority of individual disturbance patches being toward the small end of the range. For example, it has been estimated that the majority of natural-disturbance patches in original northeastern forest caused by wind, water, or pathogens commonly occurred in gaps smaller than 0.05 acre in size (Runkle 1982). However, while the great majority of disturbance patches are relatively small, the few large disturbance patches that do occur account for a substantial amount of all young forest (e.g., greater than 40% of total blowdown-patch area in northern hardwood forest) and likely provide important habitat for early-successional wildlife species that are area-sensitive (Lorimer and White 2003).

Larger patch sizes tend to be associated with more frequent disturbance intervals, but a range of patch sizes occur across all four of the general forest types discussed here. Historically, the largest individual wind- and fire-disturbance patch sizes appear to range from about 700 ha in northern hardwood forest to more than 1,000 ha in pitch pine-oak barrens in the northeast (Lorimer and White 2003). Disturbance patterns are spatially nonrandom, and are highly influenced by soil and topographic features and human-settlement patterns (Lorimer 2001). Natural disturbances often overlap and as a result some trees never fully mature before a subsequent disturbance destroys them, while other trees can attain old-growth status if they escape natural disturbance over two or more centuries.

Young forests were extremely common in Massachusetts during the late 19th and early 20th century as abandoned farmland reverted to forest cover (Figure 4-29). Today, however, only 5% of forestland in the state occurs in an early-successional (seedling/sapling) condition (Alerich 2000). Early-successional habitats are currently less common in southern New England than they were in pre-settlement times (Litvaitis 1993, DeGraaf and Miller 1996). Wind events still provide some young forest in Massachusetts today, but the impact of fire and beaver flooding on the landscape has been curtailed as a result of European settlement and subsequent development (Askins 2001).

Fire has largely been excluded from the Massachusetts landscape. Residential developments are now dispersed throughout the pitch pine-oak barrens and oak forests of eastern Massachusetts where fire historically provided early-successional habitat. It is more difficult to appreciate the loss of early-successional habitat that resulted from beaver flooding because beaver are active on the Massachusetts landscape today, and continually cause problems for people by plugging road culverts and temporarily flooding well and leach fields in residential areas.

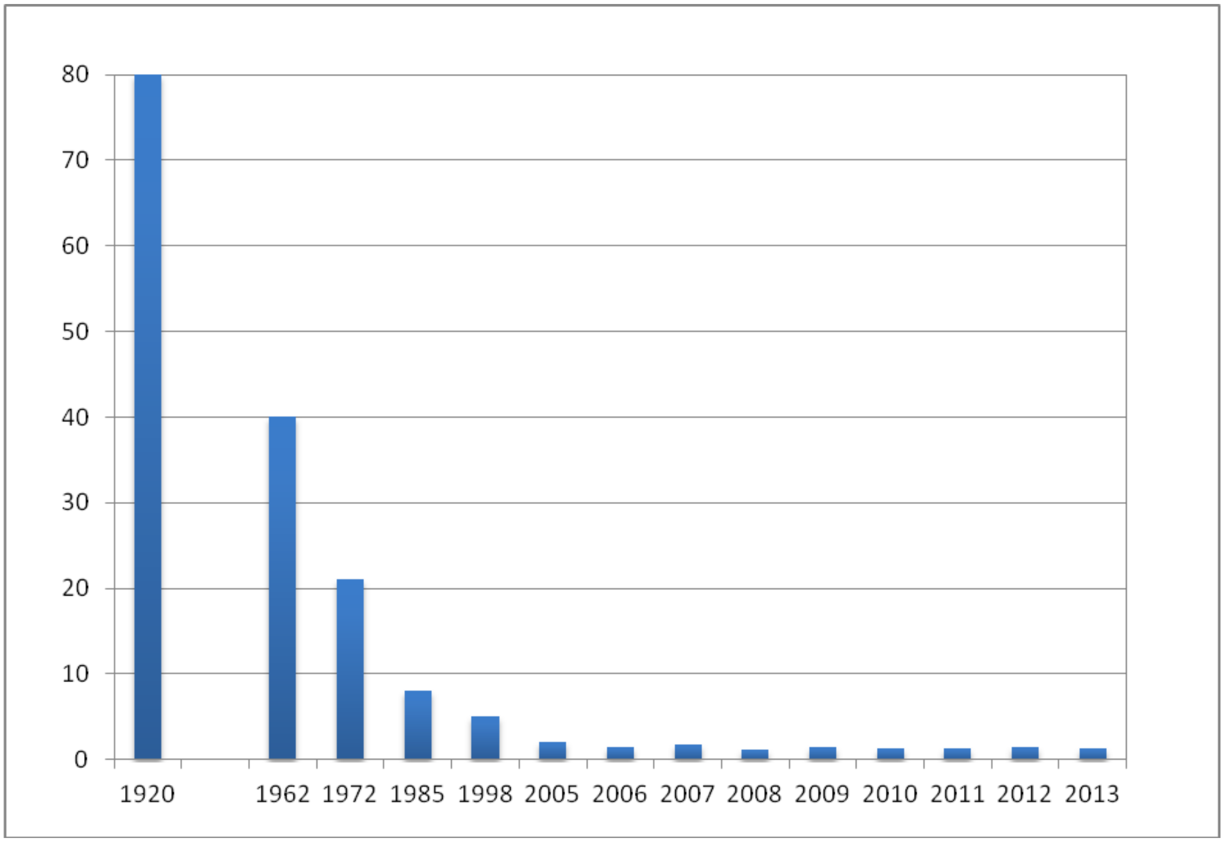


Figure 4-29: Percent early successional (seedling/sapling) forest in Massachusetts (U.S. Forest Service data).

Given current damage to the built environment caused by beaver activity, it may be surprising for some to realize that beaver flowages currently occupy far smaller areas of what is now Massachusetts than during pre-settlement times. Beaver activity historically occurred most frequently on lower slopes and along low-gradient streams in Massachusetts (Howard and Larson 1985). These low-lying sites have generally been the focus of human development in Massachusetts, and therefore no longer support or tolerate extensive beaver activity.

We simply do not know the extent of these historical beaver-influenced habitats. However, we do know that the Massachusetts Bay Colony in what is now southeastern Massachusetts reported shipments of over 6 tons of beaver pelts to Britain in the 1620s (Foster et al. 2002). If we use an average weight of 1.3 pounds for a medium-sized beaver pelt and we know that 6 tons equal 12,000 pounds, that equals about 9,230 beaver. While these shipments likely included some pelts trapped from inland areas, it is still sobering to consider that few or no beaver occur today in many portions of southeastern Massachusetts. Likewise, we know that during the 5-year period from 1652 to 1657, fur trader John Pynchon shipped 8,992 beaver pelts from Springfield, Massachusetts, in the Connecticut River drainage (Judd 1857 in DeGraaf and Miller 1996). In contrast, approximately 6,500 beaver pelts were tagged by all licensed trappers in the entire state of Massachusetts during the 5-year periods from 1985-1990 and 1990-1995 (MassWildlife, unpublished data). In 1996, ballot referendum "Question One" was passed, which prohibited or restricted the use of many types of traps, and since then average annual harvests have been 157% below pre-1996 averages (http://www.mass.gov/eea/agencies/dfg/dfw/fish-wildlife-plants/mammals/managing-beaver.html). In pre-colonial New York State, beaver-created floodplains occurred on about one million acres, or 3.5% of the state. The extent of these floodplains is now reduced by 65% (Gotie and Jenks 1982 in Hunter et al. 2001).

Historically, as dams were abandoned after beaver food resources (primarily tree bark and twigs) became depleted, the impoundments slowly drained, and succeeded first to wet meadow, and then to shrubland and young forest as former impoundments dried more completely. After adequate woody growth become reestablished, beaver typically reoccupied these low-lying sites, built new dams, and began the dynamic process of habitat modification all over again. Because human development in Massachusetts is concentrated in low-lying areas along rivers and streams where beaver activity is largely excluded, an important source of young-forest habitat formerly associated with these sites has been substantially diminished.

Shrublands

Common upland shrubs within ephemeral shrublands in the northeastern United States include blackberry, raspberry, and blueberry (Latham 2003, Wagner, et al. 2003). Rare species associated with shrublands in the northeastern U.S. tend to occur in enduring shrub habitats as opposed to ephemeral shrub habitats (Latham 2003), and this may be especially true for Lepidoptera (Wagner et al. 2003). Recent work in Massachusetts indicates that shrublands along powerline corridors and at reclaimed abandoned-field sites support a diverse assemblage of Lepidoptera, but do not typically support rare species of butterflies and moths (King and Collins 2005). Overall, shrublands are the most important natural-community type for rare and endangered Lepidoptera in Massachusetts (Wagner et al. 2003).

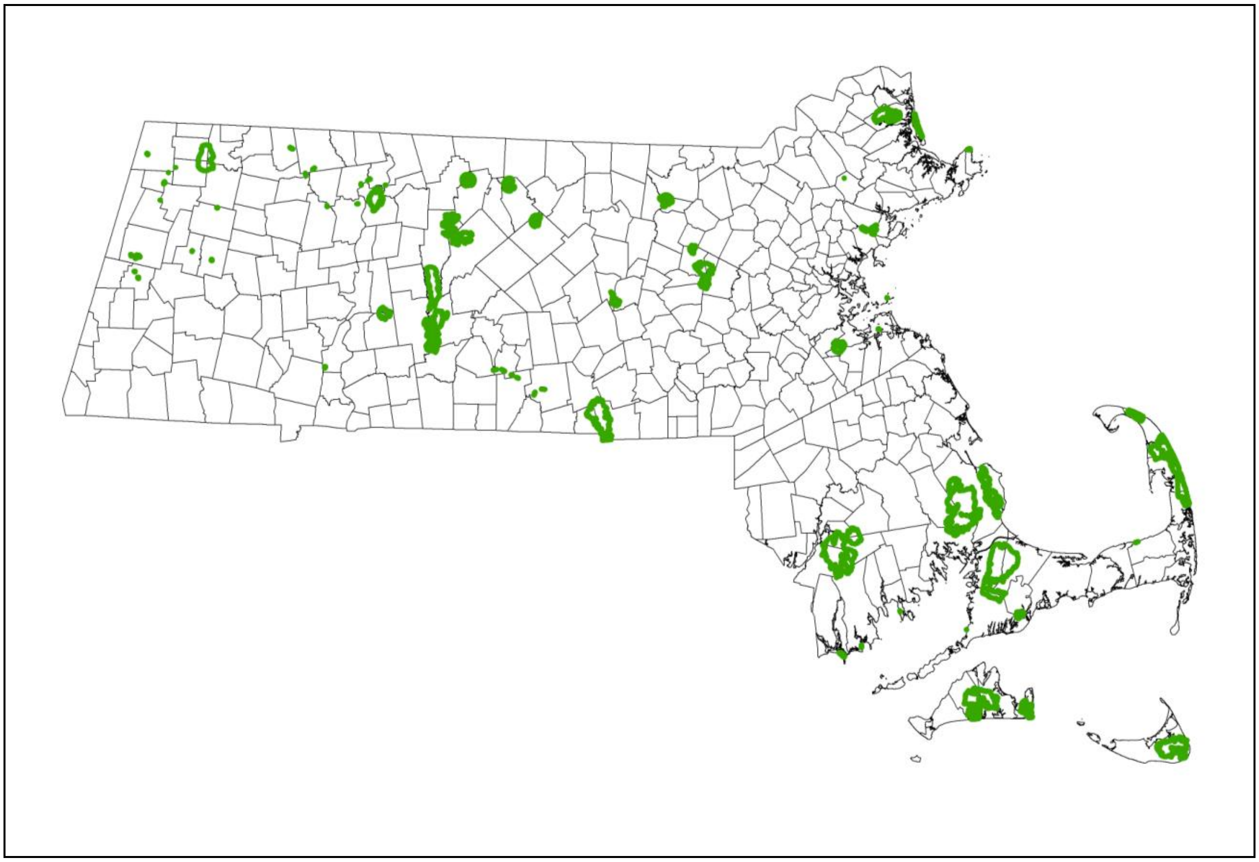


Figure 4-30. Locations of Some Young Forest and Shrubland Species Populations in Massachusetts.

Data from NHESP database.

Species of Greatest Conservation Need in Young Forests and Shrublands

Twenty-eight SGCN are assigned to the Young Forests and Shrublands habitat (Table 4-24).

Among vertebrate wildlife species in New England, 13% (3 of 13) of amphibians, 62% (16 of 26) of reptiles, 37% (79 of 214) of birds, and 72% (46 of 64) of mammals use shrub/old-field habitats (DeGraff and Yamasaki 2001). Some vertebrate species demonstrate preferred use of shrub/old-field sites, including reptiles like the Eastern Ratsnake, Eastern Hog-nosed Snake, and Spotted Turtle; birds such as the Willow Flycatcher, Blue-winged Warbler, and Song Sparrow; and mammals like the New England Cottontail, White-footed Mouse, and Ermine (DeGraff and Yamasaki 2001). Lagomorphs can be considered obligate users of shrubland habitats, and species such as Bobcat that prey on lagomorphs will certainly use shrubland habitat, but may use other habitat types as well to secure alternative prey sources (Fuller and DeStefano 2003).

New England Cottontail, American Woodcock, and Ruffed Grouse are closely associated with young-forest and shrubland habitat. The dense shrub component provides significant cover essential to these species that suffer very high natural predation. The abundance of woody browse is clearly very important for cottontails in winter, and diverse herbaceous vegetation provides both cottontail and Ruffed Grouse ample food resources during the growing season. The hydrologic regime of a site greatly influences use by woodcock, as they probe the soil for invertebrates and thus there is a finite period when soil conditions are conducive to efficient foraging. Because these habitats tend to be ephemeral on the landscape, active management is necessary to either maintain suitable young forest/shrubland patches or to create new ones. Patch size is also an important consideration, with 10-20-acre patches being the minimum size to ensure these species can meet their basic life requirements.

The rare plant species associated with young forests are all herbaceous species, except for American Bittersweet, which is a vine. All are typically found in canopy openings in young forests. Chestnut-colored Sedge is found in transitional areas in old fields and forest edges with calcareous seeps. Long-bracted Green Orchid is also found in openings in forested seeps. Both Wild Lupine and Wild Pink are observed in dry openings in young forests and along roadsides and paths. American Bittersweet in Massachusetts is observed in areas of rocky slopes with open canopies.

Table 4-24: Species of Greatest Conservation Need in Young Forests and Shrublands

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Coluber constrictor*	North American Racer
	Heterodon platirhinos	Eastern Hog-nosed Snake
	Opheodrys vernalis	Smooth Greensnake
	Pantherophis alleghaniensis	Eastern Ratsnake
Birds	*Antrostomus vociferus*	Whip-poor-will
	Bonasa umbellus	Ruffed Grouse
	Chaetura pelagica	Chimney Swift
	Coccyzus erythropthalmus	Black-billed Cuckoo
	Colinus virginianus	Northern Bobwhite
	Falco sparverius	American Kestrel
	Geothlypis philadelphia	Mourning Warbler
	Oreothlypis ruficapilla	Nashville Warbler
	Pipilo erythrophthalmus	Eastern Towhee
	Scolopax minor	American Woodcock
	Setophaga discolor	Prairie Warbler
	Setophaga pensylvanica	Chestnut-sided Warbler
	Spizella pusilla	Field Sparrow
	Toxostoma rufum	Brown Thrasher
	Vermivora chrysoptera	Golden-winged Warbler
	Vermivora pinus	Blue-winged Warbler
	Zonotrichia albicollis	White-throated Sparrow
Mammals	*Synaptomys cooperi*	Southern Bog Lemming
	Sylvilagus transitionalis	New England Cottontail
Plants	*Carex castanea*	Chestnut-colored Sedge
	Celastrus scandens	American Bittersweet
	Coeloglossum viride	Long-bracted Green Orchid
	Lupinus perennis	Wild Lupine
	Silene caroliana ssp. *pensylvanica*	Wild Pink

Threats to Young Forest and Shrubland Habitat

IUCN Threat 1: Residential and Commercial Development

Development and forest-cutting practices are likely the two biggest threats to young-forest habitat. Recent census data shows that Massachusetts is the fastest-growing state in the Northeast, and development continues to convert forest and agricultural sites to residential and suburban developments. According to Mass Audubon's recent *Losing Ground: Planning for Resilience* report (Massachusetts Audubon Society 2014), approximately 38,000 acres of forested or otherwise undeveloped land were developed in Massachusetts between 2005 and 2013 (an annual average of about 4,750 acres per year or 13 acres a day). While the rate of development in this 8-year period is less than the estimated 40 acres a day at the time of the previous State Wildlife Action Plan in 2005, it also includes the decline in development that resulted from the great recession of 2007-2010. Development trends are expected to continue to increase (Lautzenheiser et al. 2014). Another concern is that development of abandoned agricultural sites in Massachusetts negatively impacts some of our most valuable habitat patches.

IUCN Threat 2: Agriculture and Aquaculture

See the description of threats from agriculture to forests in the Upland Forests narrative, above.

IUCN Threat 3: Energy Production and Mining

Sand and gravel extraction results in conversion of young forests and shrublands to often unsuitable habitat. Once extraction is completed, these areas become prime sites for residential or commercial development, leading to permanent loss of habitats.

IUCN Threat 4: Transportation and Service Corridors
Transportation and service corridors are not a major threat to young forests and shrublands in Massachusetts.

IUCN Threat 5: Biological Resource Use
Human activity, primarily forest-cutting practices, can potentially offset some negative impacts on the creation of young-forest habitat that result from loss of beaver floodlands, fire, and other natural disturbances. However, harvesting on land that remains in forest use tends to occur as partial cuts that remove about one-third of the standing volume, and thus do not produce young-forest habitat. In addition, total harvesting across Massachusetts forestlands has declined by about 50% between 2007 and 2013; as a result, the availability of young-forest habitat continues to decline (Butler 2014).

Many private landowners report aesthetic concerns about even-aged cutting practices (especially clearcutting) that provide young-forest habitat, yet these habitats can be heavily utilized by rare reptile populations like Eastern Ratsnake due to their paucity in the forested landscape of Massachusetts. In addition to aesthetic concerns, diverse landowner objectives, declining average size of land holdings, and frequent turnover of private forestlands present major challenges to managing forest habitats to benefit wildlife (Brooks and Birch 1988). As a result, the availability of young forest-habitat remains low in Massachusetts.

IUCN Threat 6: Human Intrusions and Disturbance
Recreational use for trails and other activities can increase the interaction between large-bodied snakes, like Eastern Ratsnake and racers, and people, leading to mortality and collection of these species. Recreational uses may also become vectors for disease to wildlife populations.

Off-road vehicles present a serious threat and should be limited, particularly where their use can impact rare species.

IUCN Threat 7: Natural System Modifications
Pre-settlement forests that formerly occupied what is now developed land likely experienced more frequent natural disturbance than other lands remaining in forest use today. Development following European settlement was focused in low-lying areas along rivers and streams because waterways provided the primary means of transporting goods, and because existing Native American clearings could be readily occupied by European settlers. Forests along waterways were formerly subjected not only to periodic wind, fire, and pathogen events that also impact forests at higher elevations, but also to repeated cycles of ice-scouring and spring flooding (along rivers), or beaver flooding and abandonment (along low-gradient streams). In addition, the second-growth forests of today are more resilient to wind disturbance than the old-growth pre-settlement forests. The disproportionate abundance of early-successional habitats that likely occurred in forested sites that are now developed for human use must be replaced today in somewhat higher elevation forests, and even-aged silvicultural practices can provide ecologically and economically sustainable early-successional habitats for wildlife.

In addition, beaver impacts on forests are reduced not only within developed portions of the landscape (e.g., within cities and towns), but also adjacent to infrastructure, such as roads. that supports development. Beaver activity is understandably restricted by humans wherever a road crosses a stream, in order to avoid damage to the road. Beaver activity is typically constrained along a reach of stream above and below the road crossing, and the potential for beaver-generated young forest is correspondingly reduced, regardless of whether or not areas upstream and downstream of the crossing are developed.

Past land use (grazing) has caused changes in soils and moisture-holding capacities, resulting in somewhat dry habitats, and reducing natural pre-settlement variation of matrix forests and its habitats.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Exotic species are widely recognized as the most important threat to rare species after habitat destruction (Wilcove et al. 1998, Wilson 1992), and the economic cost of invasive exotic control can be enormous (OTA 1993, Pimentel et al. 2000). Particularly problematic in young forests are the shrub species of Glossy Buckthorn (*Frangula alnus*), Common Buckthorn (*Rhamnus cathartica*), and Autumn Olive (*Elaeagnus umbellata*). If left unchecked, invasive exotic plants can quickly become the dominant species, displacing native species and degrading ecosystems (Mack et al. 2000).

Invasive plants often thrive on disturbance (Hobbs and Huenneke 1992, Hobbs and Humphries 1995), a concern because maintenance of early-successional habitat such as shrubland and young-forest habitat is dependent on disturbance. Early control measures, when the invasion is relatively contained, are preferred to minimize costs (Hobbs and Humphries 1995). Following invasive exotic control measures, it is necessary to conduct long-term monitoring to detect exotic colonizers and take early control measures as necessary to prevent costly invasions (both in a biological and economic sense).

IUCN Threat 9: Pollution
The relationship between environmental pollutants and wildlife in these habitats are not well documented.

IUCN Threat 10: Geological Events
Geological events are not a major threat to young forests and shrublands in Massachusetts, at least in the near term.

IUCN Threat 11: Climate Change and Severe Weather
Climate change may cause a shift in species composition in young forest and shrubland habitats in Massachusetts, but these habitats will be able to be maintained on the landscape with active management. Some rare plant species, such as Chestnut-colored Sedge, which currently are near their southern extent in Massachusetts, may disappear from our landscape as a result of climate change.

Conservation Actions

Direct Management of Natural Resources
While about 79% of forestland in Massachusetts is privately owned (Alerich 2000), the best opportunities in the near future for creating high-quality young-forest habitat are likely to occur on public lands. Modified even-aged silvicultural practices that address both aesthetic concerns and habitat requirements have been applied on some state lands, and can serve as a model for private lands. Young-forest habitat that results from silvicultural practices on these state lands meets specific criteria for ecological, economic, and social sustainability (Seymour et al. 2004).

In particular, landscape composition goals for state wildlife lands call for 15-20% young forest, as well as 10-15% late-successional forest. Young forest habitat is established on state wildlife lands using modified even-aged silvicultural practices. Aggregate retention cuts remove 75-85% of the overstory at one time, and retain 15-25% of the overstory in clusters of mature trees. Shelterwood retention cuts remove up to 90% of the overstory in two cuts over a period of 5-10 years, and retain at least 10% of the original overstory in both individual trees and clusters of trees. Retention of mature trees provides structural diversity as well as relatively cool, moist micro-sites. These attributes should reduce the amount of time needed for some wildlife species to reoccupy harvested sites compared to the time needed following traditional clearcutting practices. DFW may be able to encourage private forest landowners who report that wildlife habitat is an important objective to adopt these practices.

Although it is important to create young-forest habitat throughout Massachusetts, from a wildlife perspective this habitat might be better suited than grassland or forest habitat in urban or suburban landscapes where only small patches (smaller than 10 hectares) are feasible. This is because many of the organisms that nest in young forests will occupy small habitat patches and do not demonstrate the high degree of area-sensitivity common in mature forest or grassland species (Dettmers 2003). One caveat to this is that young forests near development may only provide marginal habitat due to high densities of mesopredators associated with anthropogenic landscapes, and for many species habitat in this landscape may act as a population sink. With that in mind, successful conservation of young-forest habitat and its associated species will also require the creation of such habitat in forested landscapes throughout the state. This is not only important for the animals that breed in this habitat but also for many mature forest breeders after the breeding period, as is the case for a number of species of forest birds (e.g., Wood Thrush, Scarlet Tanager; Vitz and Rodewald 2006). In addition, Eastern Ratsnake may benefit from creation of young-forest and shrubland habitats away from human development within otherwise protected landscapes.

Finally, it is important to maintain and manage ephemeral shrublands such as abandoned-field sites through periodic mowing and/or burning, and through public and private nonprofit land acquisition. Establishing, restoring, and managing these ephemeral habitats can also be accomplished through methods other than forestry, such as prescribed fire and targeted removal of invasive plant species. Addressing invasive species in young-forest and shrubland habitats is a priority conservation action. Protocols to prevent the establishment of invasive species, either through controlling potential vectors (contaminated soil, landscaping, equipment, etc.), or addressing pioneering invasive populations through early-detection—rapid-response programs are important ways of dealing with invasive species before they are impacting a habitat. Programs to proactively treat established invasive species are key to creating young-forest and shrubland habitats and should be pursued whenever possible.

Data Collection and Analysis

Intensive and continued surveying for young-forest and shrubland birds is needed, as these species are relatively easy to survey and can serve as indicators of the quality and stage of these habitats.

Eastern Ratsnakes are critically endangered in Massachusetts and North American Racers and Smooth Greensnake are emerging as species of concern. Den or wintering sites for these snakes are often unknown and seasonal movement of individuals likely varies greatly between populations and age-classes due to existing land-use and resource availability. However, the most commonly used technology for detecting movements, radio telemetry, has significant limitations due to the size of radio equipment for juvenile or small-bodied snakes, the necessity for invasive surgery to implant radios, the need for high staffing and time resources to access radio data, and the lack of ability to remotely access radio data. Satellite tags and other such technologies are not yet of a size and shape that lend themselves to use in snakes and other small wildlife. Little is known about the interactions between co-occurring snake species or even different age-classes of the same species that may inform habitat-management efforts.

Education and Outreach

Educating and informing the public about the values of young forests and shrublands and the issues related to their conservation, through agency publications and other forms of public outreach, is needed in order to instill public appreciation and understanding.

Fear, loathing, and persecution are significant risks to all snakes, but especially to large-bodied species like North American Racers and Eastern Ratsnakes. Education and information needs to be developed for visitors and landowners about the importance of these species and, as needed, what are appropriate actions during human-snake encounters. These challenges are exacerbated by reduced funding for outdoor programming at all ages.

The *Conservation Strategy for the New England Cottontail* includes an objective to make direct contact with private landowners and encourage those eligible to participate in active management of Young Forest/Shrubland habitat with funding assistance through the Natural Resources Conservation Service.

Land and Water Rights Acquisition and Protection

State and federal agencies and non-governmental organizations should work collaboratively to protect young forests and shrublands supporting populations of rare and uncommon species.

Law Enforcement

The impacts of development and off-road vehicles on young forests and shrublands used by state-listed animals and plants should be regulated and limited. There remains a need to regulate and limit the impacts of development, quarrying, and recreational use on habitats used by state-listed species. Increases in law enforcement fines and regulations would assist law enforcement personnel and could discourage illegal activities.

Law and Policy

The permitting process for habitat-management activities in and around young forests and shrublands should be streamlined, particularly for prescribed burning.

Planning

Develop detailed conservation and recovery plans for SGCN associated with young forests and shrublands. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Because shrublands and young-forest habitat is ephemeral, long-term management planning and rotational issues must be considered to maintain an adequate representation of the age classes found in this habitat in order to maintain the breadth of biodiversity supported by these habitats. For example, early-successional birds are found in varying species compositions as the time since disturbance lengthens (Schlossberg and King, 2007). This planning should involve local managers as well as regional managers, to ensure that both the quantity and quality of the habitat is maintained. Communication among local, state, and federal officials as well as private landowners and utilites can help determine best placement of this habitat to increase patch size as well as regional proximity.

Species Reintroduction and Stocking
Land managers should consider reestablishing native plant stock and native seed sources on reclaimed shrublands once invasive plants are controlled. Additionally, when managers increase the biodiversity of native plants at a site through seeding or plantings, it can also benefit vertebrate and invertebrate species that are associated with these native community types.

Links to Additional Information

- The Young Forest Project - a partnership among governmental and private agencies and organizations working to create and maintain young forest in New England, the Mid-Atlantic, and the Midwest.
- Working Together for the New England Cottontail – a partnership aimed at conserving the New England Cottontail.
- Woodcock Task Force – a partnership aimed at conserving American Woodcock.
- Managing Grasslands, Shrublands, and Young Forest Habitats for Wildlife: A Guide for the Northeast - a publication from New Hampshire Fish and Game on management of early successional habitats.
- Conservation Practices Benefit Shrubland Birds in New England – a publication from the USDA Natural Resources Conservation Service on conservation practices and shrubland birds in New England

Riparian Forest

Habitat Description

Riparian forests occur in a linear form along streams or rivers, following the stream or river meanders. Their soils and moisture levels are influenced by the adjacent streams and rivers. Riparian forests include all the types of floodplain-forest natural communities (Swain and Kearsley 2015), alluvial forests, and streamside forests. Along the bigger rivers, such as the Connecticut, the floodplain is typically quite wide; narrower streams usually have narrower riparian zones. Floodplains are of variable width, sometimes with a distinct break where the adjacent uplands occur; in other places the changes are gradual, reflecting occasional flooding and flatter topography. In general, riparian forests are flooded in the spring and dry out during the growing season, although floods may occur at anytime.

Riparian zones vary with timing, magnitude, and duration of flooding; flow rate; and the types of sediments carried and dropped by the floodwaters. These transition areas connect rivers to uplands and they provide distinct habitats in themselves. They protect the uplands from the river in flood, and protect the river by slowing runoff and absorbing inputs from the uplands.

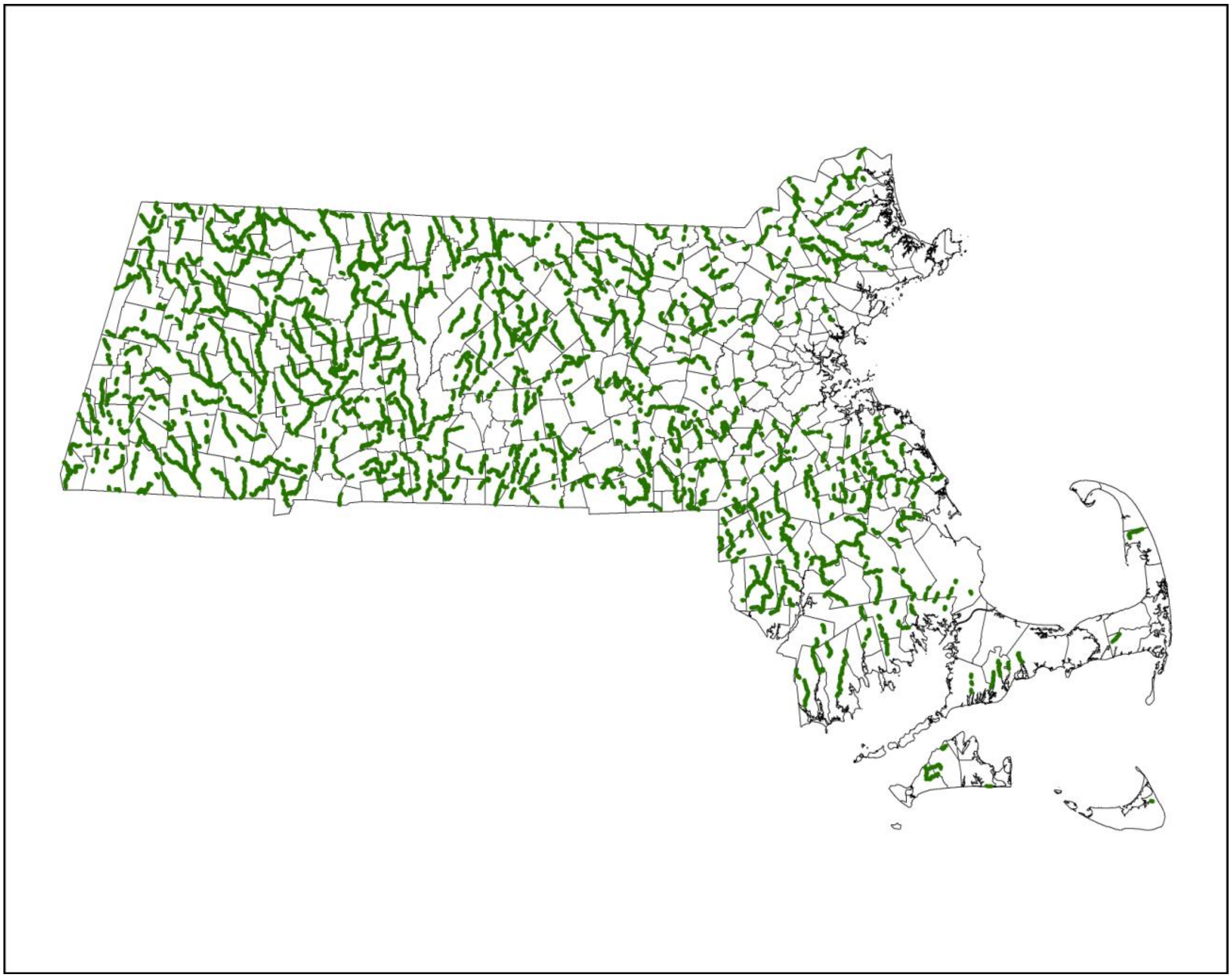


Figure 4-31: Riparian Forest in Massachusetts.

Only forested riparian areas greater than 20 acres are shown.

Species of Greatest Conservation Need in Riparian Forests

Fifty-five SGCN are assigned to the Riparian Forest habitat (Table 4-25).

Riparian forests differ from other forested wetlands in their patterns of flooding (seasonality and duration), in receiving large pulses of energy and nutrients from upstream, and in having organic material deposited and removed. The riparian forest area provides productive and diverse habitats. Beside the open water, sunlight reaches into the forest, often supporting dense shrubs, vines, and herbaceous plants, all good cover for wildlife. More diverse habitats come from the different types of vegetation supported by local topography, such as low and high areas within the riparian zone. The riparian forest provides valuable habitat for many animals, with proximity to streams and rivers, open water, diversity of vegetation, linearity, and connections up- and downstream via the river corridor. Species density is often higher in riparian forests than in other forest types (Mitsch and Gosselink, 2000). Riparian forests are often the only forests in developed areas, and provide refuge to many species in those cases. Forested wetlands along streams and rivers can be corridors for travel through otherwise unsuitable (developed) habitat for Moose, deer, and other large mammals.

Riparian forests are insect-rich habitats that attract warblers, thrushes, and other songbirds. In particular, Yellow-throated (*Vireo flavifrons*) and Warbling (*V. gilvus*) vireos, which like to nest in the canopies of riverside trees, are frequently observed in riparian forest communities. Raptors such as Bald Eagles (*Haliaeetus leucocephalus*) and Red-shouldered Hawks (*Buteo lineatus*) also use riverbank trees as perch sites. In spring floods, Wood Ducks (*Aix sponsa*) and Hooded Mergansers (*Lophodytes cucullatus*) like the shady edges of riparian forests and the interior meander scar pools. Eastern Comma butterflies (*Polygonia comma*) feed on elm and nettles. A large number of dragonfly and damselfly species, including many state-listed species, spend one to several years as larvae in the streams and rivers, and emerge to take refuge in the floodplain forest as their exoskeletons harden and they mature. Odonates also use riparian forests for roosting during inclement weather, or, in the case of crepuscular species, until twilight feeding times. Sexually mature adults typically return to patrol river and stream banks, feeding, mating, and laying eggs. Interior meander scars and sloughs function as vernal pools, providing breeding habitat for many frog species, such as Leopard and Pickerel frogs (*Rana pipiens* and *Lithobates palustris*), American Toads (*Anaxyrus americanus americanus*), and mole salamanders, such as the state-listed Blue-spotted Salamander (*Ambystoma laterale*). Riparian forests also provide sheltered, riverside corridors for dispersing mammals and migratory songbirds, as well as residents that may breed or feed in them.

Fish, reptiles, and amphibians particularly need the co-occurrence of open water and forest that makes riparian forests attractive habitat to many animal species. Many fish species rely on the feeding, spawning, and rearing habitat provided by floodplain forests. During flood events, the vegetation in floodplain forests slows water velocities, reducing erosion and providing locations for deposition of fine sediments, which might otherwise clog spawning substrates within the river channel. Perhaps most importantly for fish, floodplain forests provide allochthonous inputs (leaves, detritus, and other nutrients), stability (to prevent excessive erosion), and shade to moderate thermal regimes. Wood Turtles are most strongly associated with flowing water (streams and rivers) and adjacent early-successional uplands, but make extensive use of riparian forests as well (Fowle, 2001, Jones 2009). Spotted Turtles (*Clemmys guttata*) and Blanding's Turtles (*Emydoidea blandingii*) also move through riparian forests regularly, as they use wetlands and nesting habitat associated with these areas.

Numerous forest communities (Swain and Kearsley 2015) occur in riparian zones, providing a variety of habitats, including a rich variety of hardwood swamps that occur in low areas along rivers and streams that experience overbank flooding. The High-Terrace Floodplain Forest has a canopy of Red and Silver maples (*Acer rubrum* and *A. saccharinum*) and other rich-mesic deciduous tree species, including Sugar Maple (*A. saccharum*), Shagbark Hickory (*Carya ovata*), and Basswood (*Tilia americana*). This is classic habitat for Ostrich Fern (*Matteuccia struthiopteris*) and the associated Ostrich Fern Borer Moth. These forests often have shrub layers that include Spicebush (*Lindera benzoin*), Arrowwood (*Viburnum dentatum*), and

Nannyberry (*V. lentago*), and Ironwood (*Carpinus caroliniana*) in the sub-canopy. This forest community floods less than annually, though flooding is still an important component.

Alluvial Red Maple Swamps are similar to the High-Terrace Floodplain Forests, but flood more frequently (at least annually), and are generally located on small rivers and streams. With Red Maple as the dominant species, other co-occurring species include Silver Maple (*Acer saccharinum*), Yellow Birch (*Betula alleghaniensis*), Black Gum (*Nyssa sylvatica*), White Ash (*Fraxinus americana*), White Pine (*Pinus strobus*), American Elm (*Ulmus americana*), Hemlock (*Tsuga canadensis*), Pin Oak (*Quercus palustris*), and Swamp White Oak (*Q. bicolor*).

Alluvial Atlantic White Cedar Swamps provide a richer mix of species than do non-riparian occurrences of Atlantic White Cedar Swamps, but include the species that are primarily associated with Atlantic White Cedar, such as Northern Parula warblers and Hessel's Hairstreak (*Callophrys hesseli*) butterflies.

Other riparian-forest communities have Hemlock mixed with the cedars or deciduous species, or occurring alone in the canopy, further providing a mix of habitats for wildlife.

There are a number of Massachusetts rare plant species that may occur within riparian forests and the rich alluvial soil associated with them. Green Dragon, Purple Cress, Foxtail Sedge, Davis' Sedge, Gray's Sedge, Cat-tail Sedge, Tuckerman's Sedge, Hairy Wild Rye, Andrews' Bottle Gentian, Winged Monkey-flower, and Clustered Sanicle all grow exclusively in riparian floodplain forests, thriving in the rich alluvial soils and the annual floods of Massachusetts rivers and streams. Muskflower, Great Blue Lobelia, and Dwarf Scouring Rush grow in seeps and scours associated with these rivers and streams. Narrow-leaved Spring-beauty can be found on upper floodplain terraces. Some, such as Britton's Violet, Swamp Dock, Bristly Buttercup, Crooked-stemmed Aster, Small-flowered Agrimony, and Narrow-leaved Gentian, thrive within openings found in these forests.

Table 4-25: Species of Greatest Conservation Need in Riparian Forest

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Glyptemys insculpta*	Wood Turtle
Birds	*Cardellina canadensis*	Canada Warbler
	Parkesia motacilla	Louisiana Waterthrush
	Setophaga americana	Northern Parula
	Setophaga cerulea	Cerulean Warbler
Odonates	*Boyeria grafiana*	Ocellated Darner
	Gomphus abbreviatus	Spine-crowned Clubtail
	Gomphus descriptus	Harpoon Clubtail
	Gomphus fraternus	Midland Clubtail
	Gomphus quadricolor	Rapids Clubtail
	Gomphus vastus	Cobra Clubtail
	Gomphus ventricosus	Skillet Clubtail
	Neurocordulia obsoleta	Umber Shadowdragon
	Neurocordulia yamaskanensis	Stygian Shadowdragon
	Ophiogomphus aspersus	Brook Snaketail
	Ophiogomphus carolus	Riffle Snaketail
	Somatochlora elongata	Ski-Tailed Emerald
	Somatochlora forcipata	Forcipate Emerald
	Somatochlora georgiana	Coppery Emerald
	Somatochlora kennedyi	Kennedy's Emerald
	Somatochlora linearis	Mocha Emerald
	Stylurus amnicola	Riverine Clubtail
Lepidoptera	*Papaipema* sp. 2	Ostrich-fern Borer
Plants	*Agrimonia parviflora*	Small-flowered Agrimony

Taxon Grouping	Scientific Name	Common Name
	Arisaema dracontium	Green Dragon
	Bidens hyperborea	Estuary Beggar-ticks
	Boechera laevigata	Smooth Rock-cress
	Cardamine douglassii	Purple Cress
	Carex alopecoidea	Foxtail Sedge
	Carex davisii	Davis's Sedge
	Carex grayi	Gray's Sedge
	Carex trichocarpa	Hairy-fruited Sedge
	Carex tuckermanii	Tuckerman's Sedge
	Carex typhina	Cat-tail Sedge
	Claytonia virginica	Narrow-leaved Spring-beauty
	Crassula aquatica	Shore Pygmy-weed
	Deschampsia cespitosa ssp. *glauca*	Tussock Hairgrass
	Eleocharis intermedia	Matted Spike-sedge
	Elymus villosus	Hairy Wild Rye
	Equisetum scirpoides	Dwarf Scouring Rush
	Eragrostis frankii	Frank's Lovegrass
	Gentiana andrewsii	Andrews' Bottle Gentian
	Gentiana linearis	Narrow-leaved Gentian
	Halenia deflexa	Spurred Gentian
	Lobelia siphilitica	Great Blue Lobelia
	Ludwigia polycarpa	Many-fruited Seedbox
	Mimulus alatus	Winged Monkey-flower
	Mimulus moschatus	Muskflower
	Platanthera huronensis	Northern Green Orchid
	Ranunculus pensylvanicus	Bristly Buttercup
	Rumex verticillatus	Swamp Dock
	Sagittaria cuneata	Wapato
	Sanicula odorata	Clustered Sanicle
	Symphyotrichum prenanthoides	Crooked-stem Aster
	Viola brittoniana	Britton's Violet

Threats to Riparian Forests

IUCN Threat 1: Residential and Commercial Development

Although this habitat probably receives more protection from development than some of the other habitats because of the Massachusetts Wetlands Protection Act and other environmental laws and regulations, there is pressure on the unprotected riparian forests for both residential and commercial development, as developers will pay a premium for these lands because they provide water access. The Massachusetts Rivers Protection Act helps to protect riparian forests, requiring review by local conservation commissions of all areas within 200 feet of the banks of perennial rivers and streams, though the reality is that the protection of such areas varies widely across the Commonwealth from town to town. Additional protection is afforded these areas that lie within the 100-year floodplains, as floodplain compensatory storage and special construction to withstand flooding is required for any construction, filling, or excavation within these areas. In addition, existing development may often expand, slowly nibbling away at the forests.

IUCN Threat 2: Agriculture and Aquaculture

The nutrient-rich, moist, and often-level soils of riparian areas have frequently been converted to agricultural lands in Massachusetts. Many of Massachusetts' original riparian forests have already been converted into agricultural fields along the large rivers, such as the Sudbury, Assabet, Concord, Connecticut, Housatonic, and Hoosic rivers. Certain agricultural activities, such as haying, can pose a significant threat to Wood Turtles and Box Turtles (Jones 2009, Erb and Jones 2011). The exemplary examples of High-Terrace Floodplain Forests in the state occur mostly in western Massachusetts, where the populations are lower and there has been less development pressure for agriculture.

IUCN Threat 3: Energy Production and Mining
Energy production has had an impact on the riparian forests. Many perennial streams and rivers were dammed for water power starting in the early to mid-nineteenth century, and large dams on the major rivers remain in production today. Dams on smaller rivers changed the habitats associated with them by raising the water levels throughout. One example of energy production that has led to unstable river banks is the Northfield Mountain Pumped Storage Facility on the Connecticut River and its associated dam at Turners Falls. The dam was raised approximately 3 feet in 1970, and the river banks up-gradient are still adjusting to the changes in water-saturated soils. As part of this energy production facility, water levels fluctuate up to 10 feet a day within the main channel and the adjacent floodplain forests have been dramatically altered. Dams on both large and small rivers and streams impact the sediment transport by withholding sediments from the downstream riparian forests and floodplains.

IUCN Threat 4: Transportation and Service Corridors
The riparian forest habitat is threatened by transportation and other service corridors. Transportation, utilities, and railroad corridors cross the rivers and streams that provide the life for these riparian forests. The crossings on smaller streams and rivers may consist of undersized culverts, which restrict the flow of water, organic material and animals moving up- and downstream. Such restrictions can create deposition of material on the upstream side, and erosion or excavation on the downstream side of the crossings. Crossings on larger rivers through blocks of undeveloped land carve these lands into smaller areas, isolating from each other animal populations, which cannot cross heavily trafficked roads (Jackson et al. 2012). Increased mortality associated with transportation corridors can pose a significant threat to Wood Turtles, other turtle species, and a wide array of wildlife associated with riparian corridors (Fahrig and Rytwinski 2009).

Roads crossing riparian-forest habitats represent additional threats besides a loss of connectivity. With roads comes an increase in road salt and its associated components, chloride in particular. Between 1990 and 2011, average concentrations of chloride in streams in the northern U.S. have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into these wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations.

IUCN Threat 5: Biological Resource Use
Biological resource use is not a major threat to riparian forests.

IUCN Threat 6: Human Intrusions and Disturbance
Increased human activity in the riparian zone can pose a threat to turtles, possibly as a result of increased collection of turtles (Garber and Burger 1995). The severity of this threat in Massachusetts is unknown.

IUCN Threat 7: Natural System Modifications
Threats to riparian forests include alteration of natural hydrology through damming or other changes in the natural river flow and flood patterns, including water withdrawal and straightening streams. The more than 3,000 dams statewide have created an alternating problem of accelerated floodplain development within impoundments, and floodplain starvation between impoundments. This results in impoundments that fill with sediments, nutrients, and often contaminants. Reaches between dams become incised. As the sediment-starved channel digs deeper into the local geology, higher flood flows are needed to connect the river to the surrounding floodplain. Once the recurrence of flooding in an area drops, the temptation becomes to encourage development on these floodplains, which further exacerbates the issues associated with floodplain encroachment, as well as the costs associated with flood damage. Maintenance of natural flooding intensity and patterns is needed to maintain the vegetation and habitats in the riparian zones. Just as impounding stretches of stream causes disruption to the natural flow regime, tiling or draining riparian forests would also cause the forest and stream habitats to change drastically. Stream habitats downstream would be impacted by accelerated draining and increases in damaging flood flows.

IUCN Threat 8: Invasive and Other Problematic Species and Genes

In a 1997 statewide floodplain-forest community inventory (Kearsley 1999), nonnative plant species were observed at all floodplain-forest sites surveyed, but they appeared to be localized to areas where the canopy was opened, the herbaceous layer was cleared, and the soil was disturbed. Nonnative invasive species cause great changes in habitat by altering the structure of the shrub and herbaceous layers, and by competing with tree seedlings, which ultimately changes the canopies. For example, Japanese Knotweed (*Fallopia japonica* var. *japonica* and relatives, Giant Knotweed, *F. sachalinensis*, and a hybrid between the two, *F. x bohemica*) currently poses a great threat to riparian forests because of its ability to spread rapidly and shade out all other herbaceous plants. In addition, studies have shown reduced survival of larval amphibians living in these invaded habitats (Maerz et al. 2005). The best way to avoid its spread is to prevent its establishment by avoiding all clearing and disturbance within riparian forest areas, particularly on the sandier banks. Many other invasive species are found in riparian areas, changing the species and structural composition of the forests, and changing the habitats available to native wildlife.

IUCN Threat 9: Pollution

Although there has been a real effort in the past few years to control both point and nonpoint pollution, this remains an issue in this habitat in particular. The low-lying riparian forests receive the discharge of polluted groundwater from poorly maintained septic systems and overland untreated runoff from developed areas. They might also receive groundwater polluted with nutrients and pesticides from adjacent agricultural practices. Trash and garbage that washes (and is carried by wind) from anthropogenic areas (roadsides, yards) into rivers and streams often finds its way into backwaters in riparian forests. Such trash lodges itself and may cover the soil, preventing the growth of plants and creating a barrier for the movement of animals.

As mentioned above in IUCN Threat 4, river chloride concentrations have doubled between 1990 and 2011. This pollutant is highly toxic to freshwater life, including floodplain species (Corsi et al. 2015).

IUCN Threat 10: Geological Events

Geological events are not a great threat to riparian-forest habitat in Massachusetts.

IUCN Threat 11: Climate Change and Severe Weather

Climate change is predicted to consist of warmer temperatures and an increase in severe-weather events. For riparian-forest habitats, this is likely to result in a higher evapotranspiration rate as trees and herbaceous plants respond to the higher temperatures. Higher rates of evaporation and transpiration may cause a drawdown of the groundwater table, and may change the plant-community structure. In contrast to the higher rates of evapotranspiration, climate change in Massachusetts is also predicted to result in higher precipitation rates, and, in the past two decades, groundwater tables region-wide have increased to their highest levels in the past 500 years (Pederson et al. 2013, 2014, Newby et al. 2014, Weider and Boutt 2010).

Each riparian-forest community will respond to the combinations of conditions that most affect it. Some are likely to become wetter where there is higher groundwater input, while others may become drier. Species that thrive in the current conditions may no longer be able to survive. Several of the rare plant species associated with this habitat are located near their southern extent, including Estuary Beggar-ticks, Dwarf Scouring Rush, Spurred Gentian and Bristly Buttercup. An increase in temperatures may further reduce these species in the state. Alternatively, a few species (Winged Monkey-flower, Crooked-stemmed Aster and Britton's Violet) are near their northern extents and an increase in these plant species may be observed.

Severe weather events, such as Superstorm Sandy, are predicted to increase. Such storms would be expected to bring high precipitation and high winds. High precipitation will lead to an increase in flooding outside of the usual spring floods, with winds toppling trees and bringing other debris into the rivers and streams, and thus into the riparian forests. As these storm events are so unpredictable, it is difficult to know exactly how this might impact this habitat other than bringing flooding, sediment, and debris into the habitat. New openings in the forest canopy are likely, which may provide an opening for invasive species.

Conservation Actions

Direct Management of Natural Resources
Manage already-protected riparian forests to remove exotic invasive species, particularly in the vicinity of known rare plant and animal occurrences, including but not limited to high-priority Wood Turtle populations and exemplary floodplain-forest natural communities.

Data Collection and Analysis
Research riparian forest SWAP species to determine their actual distributions and population sizes in Massachusetts, as many species are undersurveyed and little-understood.

Continue participation in regional efforts to monitor the distribution, abundance, and trends in Wood Turtle populations and to assess Wood Turtle genetics.

Conduct surveys for additional populations of rare plant species associated with riparian forests (i.e., Crooked-stemmed Aster, Gray's Sedge, Tuckerman's Sedge and Cat-tail Sedge).

Conduct additional surveys of odonate species in floodplain forests to better understand the possible importance of these areas as refugia and foraging habitats for rare and state-listed species.

Combine geospatial approaches to assess the importance of intact floodplain forests in contributing to water quality and open-water habitats of rare and/or state-listed species. Models should be used to prioritize restoration, land conservation, and regulatory protection of floodplain forests and associated aquatic habitats.

Initiate inventories of riparian forests to supplement the state report on floodplain forests (Kearsley 1999), including a report that includes management recommendations for wildlife and plant habitats.

Research the impacts of invasive species on wildlife habitats in riparian forests.

Education and Outreach
Inform and educate the public about the values of these habitats and the issues related to their conservation through articles in conservation-organization publications and other forms of public outreach, in order to instill public appreciation and understanding.

Harvest and Trade Management
Continue efforts to educate the public about the effects of collection on turtle populations.

Land and Water Rights Acquisition and Protection
Permanently protect riparian forests supporting populations of rare and uncommon animals and plants.

Set priorities for land protection, using data from new surveys of riparian forests.

Law Enforcement
Regulate and limit the impacts of development and hydrologic alterations on riparian forest used by state-listed animals and plants.

Enforce bans on illegal use of off-road vehicles in riparian forests.

Law and Policy
The Rivers Protection Act of 1996 added a 200-foot-wide riparian zone to either side of perennial rivers and streams, except in heavily developed areas. Research should be conducted on whether this law has had any impact on the protection of riparian forests, and with it the protection of the rare plants and animals that need these habitats to survive.

Planning
Develop detailed conservation and recovery plans for SGCN associated with riparian forests. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations. Specific recommendations should be prepared for the most viable sites of riparian forest.

Species Reintroduction and Stocking
On lands owned by the DFW, and potentially on lands owned by other land conservation partners (DCR, The Trustees of Reservations, Mass Audubon, The Nature Conservancy, and some land trusts), reintroduction of rare plant and animal species in appropriate habitats should be considered, where the habitats can be appropriately managed and maintained for these species.

Vernal Pools

Habitat Description

Vernal pools are unique wildlife habitats best known for the amphibians and invertebrate animals that use them to breed and reproduce. These small wetland basins, also known as ephemeral pools, autumnal pools, or temporary woodland ponds, typically fill with water in the autumn or winter months due to rainfall and rising groundwater and remain ponded through the spring and into summer. As ambient air temperatures rise and the growing season advances during spring, vernal pools lose water to evaporation, transpiration, and falling water tables, eventually becoming completely dry by the middle or end of summer each year (or at least every few years). This wet-dry cycle, described as the vernal pool's hydroperiod, precludes the establishment of permanent fish populations in the basin, which is critical to the reproductive success of many amphibian and invertebrate species that rely on breeding habitats free of fish predators.

Vernal pools are relatively common in Massachusetts, except in highly urbanized areas. In 2000, the NHESP undertook a major project to identify locations of possible vernal pools throughout Massachusetts, conducting a visual evaluation of aerial photographs for evidence of small waterbodies that might be expected to support pool-dependent wildlife. Approximately 30,000 such features were identified statewide (Figure 4-32); these sites are called Potential Vernal Pools (PVPs). Indeed, most PVPs that are field-checked are confirmed to be functioning as vernal-pool habitat. Although some PVPs do not function as vernal pools, the PVP data set likely underestimates the true number of vernal pools occurring across the Massachusetts landscape, because the reliance on aerial photo-interpretation for their identification very likely missed pools that are very small, occur beneath conifer canopies, and/or occur within wooded swamps. Locations of PVPs can be obtained via a Geographic Information System (GIS) datalayer (NHESP Potential Vernal Pools) made available on the MassGIS website (see http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/pvp.html).

Vernal pools can be certified to qualify the pools for legal protections afforded by the Massachusetts Wetlands Protection Act, the Department of the Army General Permits for Massachusetts (2015), and several other state and local laws. The certification process, which is administered by the NHESP, involves documentation of minimum physical and biological criteria presumed to be strong indicators of vernal pool habitat (e.g., presence of a confined basin depression holding water during the spring and supporting breeding activity of obligate vernal pool species). Anyone can survey a vernal pool, document its physical and biological characteristics, and submit a completed report to the NHESP for possible certification of the pool as vernal-pool habitat. Vernal-pool observation reports (also called certification applications) received by the NHESP are then reviewed for approval in accordance with certification guidelines established by the Program. Additional details about vernal-pool certification, including the NHESP *Guidelines for the Certification of Vernal Pool Habitat*, are available on the NHESP website (see http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/vernal-pools/vernal-pool-certification.html).

Over 7,000 vernal pools are designated Certified Vernal Pools (CVPs) in Massachusetts currently (Figure 4-33), and the number continues to grow annually as more biological surveys are completed. Since the certification of vernal pool habitat is a voluntary process and relies heavily on efforts of the general public, the overall distribution of CVPs differs greatly from that of PVPs. However, there is considerable overlap, as many PVPs ultimately become CVPs. Locations of CVPs can be obtained via a Geographic Information System (GIS) datalayer (NHESP Certified Vernal Pools) made available on the MassGIS website (see http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/cvp.html).

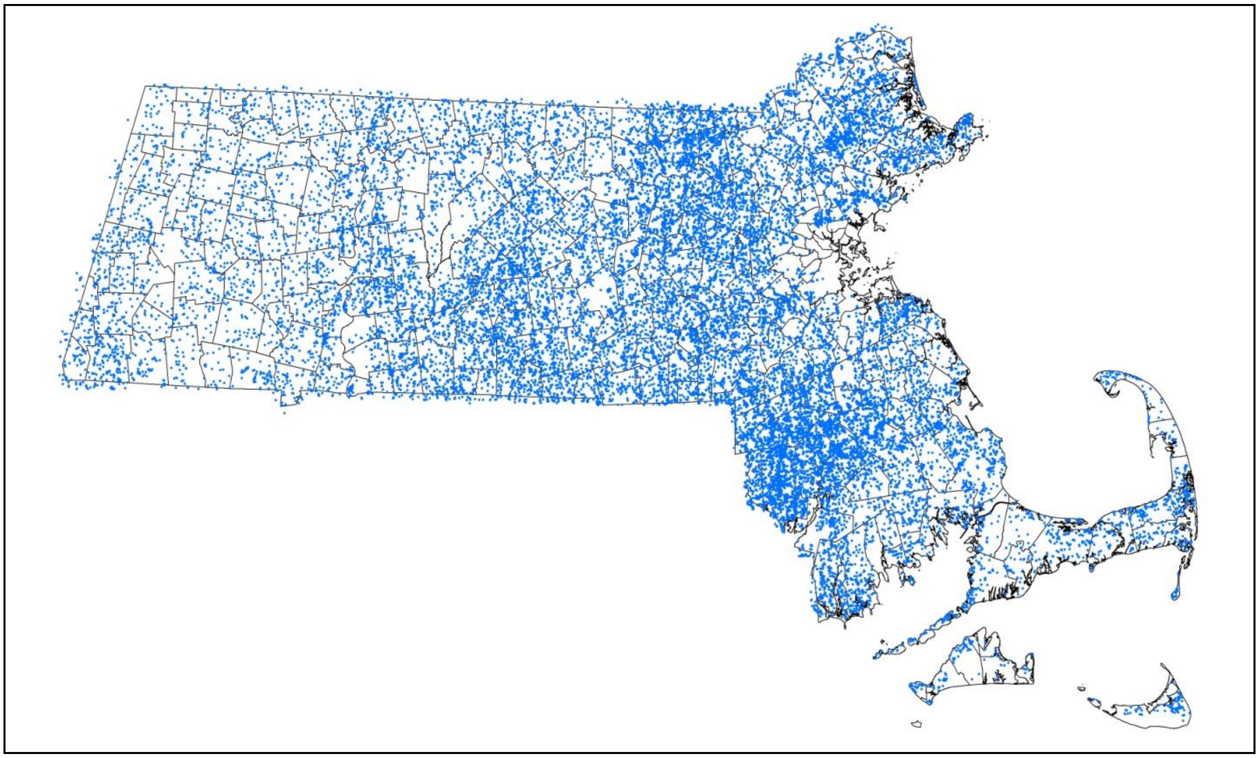


Figure 4-32: Potential Vernal Pools in Massachusetts.

Data from NHESP.

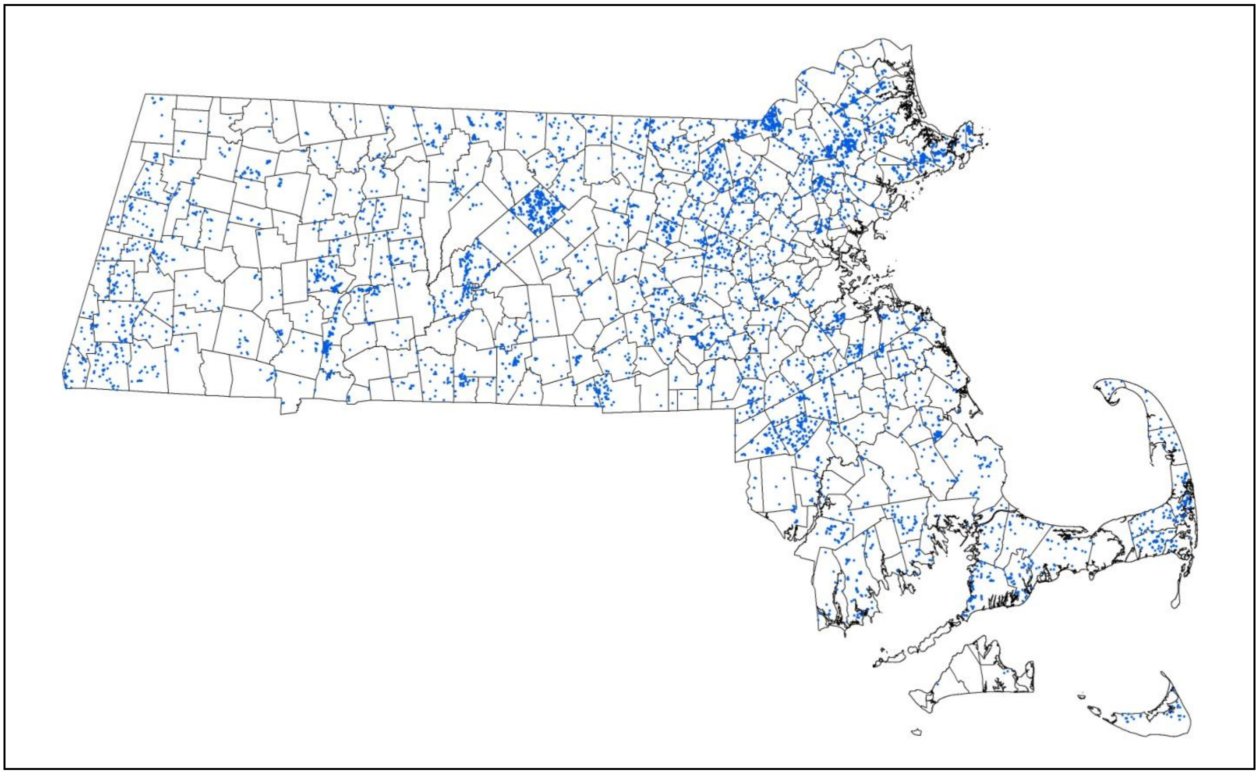


Figure 4-33: Certified Vernal Pools in Massachusetts.

Data from NHESP.

Species of Greatest Conservation Need in Vernal Pools

Fourteen SGCN are assigned to the Vernal Pools habitat (Table 4-26).

A number of taxa are considered vernal pool *obligates*, meaning they require vernal pools to complete critical stages of their life cycles (typically reproduction) and, therefore, maintain viable populations. Examples of some common vernal-pool obligates in Massachusetts include Wood Frog (*Lithobates sylvaticus*), Spotted Salamander (*Ambystoma maculatum*), and Eastern Fairy Shrimp (*Eubranchipus vernalis*). Massachusetts SGCN considered to be vernal-pool obligates include Jefferson Salamander (*Ambystoma jeffersonianum*), Blue-spotted Salamander (*Ambystoma laterale*), Marbled Salamander (*Ambystoma opacum*), Eastern Spadefoot (*Scaphiopus holbrookii*), and Intricate Fairy Shrimp (*Eubranchipus intricatus*) (Table 4-26).

In fact, Eastern Spadefoot tends to require pools that are so ephemeral that they do not always hold water long enough to meet the regulatory definition of “vernal pool habitat” under the Massachusetts Wetlands Protection Act (M.G.L. c.131 s.40 and 310 CMR 10.00), thus highlighting the potential vulnerability of certain types of vernal pools in Massachusetts.

Many other taxa, although not absolutely dependent on vernal pools, heavily use vernal pools as a resource for certain needs (e.g., feeding, breeding, overwintering, aestivating, hydrating) when other wetland types are less available or are near their biological carrying capacities. In those respects, vernal pools may function as stepping-stone habitats between distant wetlands, or as supporting habitats when resources in other wetlands become limited. Examples of Massachusetts biota that frequently use vernal pools to help meet their life-history requirements include Four-toed Salamander (*Hemidactylium scutatum*), Eastern Newt (*Notophthalmus viridescens*), Fowler's Toad (*Anaxyrus fowleri*), American Toad (*Anaxyrus americanus*), Spring Peeper (*Pseudacris crucifer*), Gray Treefrog (*Hyla versicolor*), Green Frog (*Lithobates clamitans*), Pickerel Frog (*Lithobates palustris*), Northern Leopard Frog (*Lithobates pipiens*), Blanding's Turtle (*Emydoidea blandingii*), Spotted Turtle (*Clemmys guttata*), Eastern Box Turtle (*Terrapene carolina*), Wood Turtle (*Glyptemys insculpta*), Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), Water Shrew (*Sorex palustris*), Spatterdock Darner (*Rhionaeschna mutata*), Emerald Spreadwing (*Lestes dryas*), Lyre-tipped Spreadwing (*Lestes unguiculatus*), Agassiz's Clam Shrimp (*Eulimnadia agassizii*), American Clam Shrimp (*Limnadia lenticularis*), fingernail clams, amphibious air-breathing snails, leeches, diving beetles, water scorpions, dobsonflies, whirligig beetles, caddisflies, False Hop Sedge (*Carex lupuliformis*), Tuckerman's Sedge (*Carex tuckermanii*), and Swamp Cottonwood (*Populus heterophylla*).

In Massachusetts, False Hop Sedge and Swamp Cottonwood are only found in vernal pools that receive runoff from adjacent basalt outcrops and bedrock, thus occurring in a very limited portion of the state. In addition, Swamp Cottonwood is at the northern extent of its range in Massachusetts; this population of a dioecious species is apparently not producing seed and may be a single clone. Tuckerman's Sedge occupies a wider set of habitats, but all have the same hydrologic regime of early-season inundation followed by later-season drawdown.

Table 4-26: Species of Greatest Conservation Need in Vernal Pools

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Ambystoma jeffersonianum*	Jefferson Salamander
	Ambystoma laterale	Blue-spotted Salamander
	Ambystoma opacum	Marbled Salamander
	Scaphiopus holbrookii	Eastern Spadefoot
Reptiles	*Clemmys guttata*	Spotted Turtle
	Emydoidea blandingii	Blanding's Turtle
Mammals	*Sorex palustris*	Water Shrew
Crustaceans	*Eubranchipus intricatus*	Intricate Fairy Shrimp
	Eulimnadia agassizii	Agassiz's Clam Shrimp
	Limnadia lenticularis	American Clam Shrimp
Odonates	*Rhionaeschna mutata*	Spatterdock Darner
Plants	*Carex lupuliformis*	False Hop Sedge
	Carex tuckermanii	Tuckerman's Sedge
	Populus heterophylla	Swamp Cottonwood

Threats to Vernal Pools

Limited public knowledge and education about the importance of vernal pool habitat, combined with deficiencies in regulatory protections and oversight, contribute to the vulnerability of vernal pools to a variety of threats in Massachusetts. In general, the relatively small sizes of vernal pools and their periods without water often make them inconspicuous on the landscape, only exacerbating their vulnerabilities.

Following is a list of specific threats to vernal pool habitats in Massachusetts.

IUCN Threat 1: Residential and Commercial Development

Land development that involves clearing, grading, filling, and/or building construction and associated landscaping may result in the direct filling and permanent physical loss of vernal pools. Blasting activities downslope of vernal pools can break perched water tables from below and thereby permanently destroy the hydrologic function of affected pool basins. Increased impervious surface in the watershed, particularly in areas adjacent to a pool, may result in altered hydrologic function, reduced water quality, increased nutrient-loading and sedimentation, increased salinization, and/or changes in surface-water temperatures (Snodgrass et al. 2008, Corsi et al. 2015). Many vernal pool-obligates also require the terrestrial habitats surrounding vernal pools to complete their life cycles; vernal-pool function can be indirectly disrupted when residential and commercial developments destroy those terrestrial habitats (Homan et al. 2004). When development occurs in the immediate vicinity of pools and/or creates physical barriers between pools, the ability of organisms to access and populate those pools is impaired, thus affecting the habitat function of the pools and the metapopulation dynamics of associated SGCN. Development and associated traffic can also lead to direct mortality of amphibians and reptiles (Andrews et al. 2008), which is especially concerning for SGCN whose reproductive strategies are based on high annual adult survivorship (e.g., Blanding's Turtle, Spotted Turtle).

Certified Vernal Pools receive substantial regulatory protection from direct loss to residential and commercial development in Massachusetts. However, only a small percentage (less than 25%) of vernal pools in the state are currently recognized as CVPs. Some of the remaining vernal pools are protected from direct loss by local regulations, but not all municipalities have established such regulations, and those that have vary in their level of oversight and enforcement. Terrestrial habitats surrounding vernal pools are highly vulnerable to residential and commercial development, as there are few legal protections for those areas besides the MESA.

Development pressure in Massachusetts is high. Despite relatively strong environmental regulations in the state, residential and commercial development is considered a significant threat to its vernal-pool habitats.

IUCN Threat 2: Agriculture and Aquaculture
Agricultural development involving clearing, grading, or filling may result in the direct filling and permanent physical loss of vernal pools. Agricultural dumping may physically or chemically alter vernal pools. Runoff from agricultural fields may negatively alter vernal-pool chemistry and harm associated amphibians via introduction of fertilizers, pesticides, or herbicides (Rouse et al. 1999, Burgett et al. 2007, Baker et al. 2013).

Agricultural-development pressure in most parts of Massachusetts is relatively low, and demand for organic products from existing operations is relatively high. Agricultural abandonments continue to occur and tend to result in creation of new vernal-pool habitats, as abandoned farm ponds and watering holes naturally accumulate organic matter over time and become suitable for use by obligate pool-breeding species. All of these factors help to mitigate the impacts of agriculture on vernal-pool habitat. However, certain types of agricultural activities are exempt from most environmental regulations in Massachusetts, including the Wetlands Protection Act. Furthermore, the limited exemptions are sometimes perceived by landowners as unlimited blanket exemptions, and so unlawful loss of vernal pools to agricultural development does occur on occasion.

IUCN Threat 3: Energy Production and Mining
Energy production or mining activities that involve clearing, grading, or filling may result in the direct removal, filling, and permanent physical loss of vernal pools. Blasting activities downslope of vernal pools can break perched water tables from below and thereby permanently destroy the hydrologic function of affected pool basins. Many vernal-pool obligates also require the terrestrial habitats surrounding vernal pools to complete their life cycles; vernal pool function can be indirectly disrupted when energy production or mining activities alter or destroy those terrestrial habitats. When such activities occur in the immediate vicinity of pools or create physical barriers between pools, the ability of organisms to access and populate those pools is impaired, thus affecting the habitat function of the pools and the metapopulation dynamics of associated SGCN. In other cases, vernal-pool obligates may actually colonize mining sedimentation pools. Those pools are often considered population sinks, as they are unprotected, are reconfigured regularly to fit the needs of the mining operation, and may ultimately be filled, thereby leaving the newly dependent animals without a breeding site.

Certified Vernal Pools receive substantial regulatory protection from direct loss to energy production or mining activities in Massachusetts. However, only a small percentage (less than 25%) of vernal pools in the state are currently recognized as CVPs. Some of the remaining vernal pools are protected from direct loss by local regulations, but not all municipalities have established such regulations, and those that have vary in their level of oversight and enforcement. Terrestrial habitats surrounding vernal pools are highly vulnerable to energy production and/or mining activities, as there are few legal protections for those areas besides the MESA.

Energy production and mining pressure in Massachusetts is probably considered moderate. Despite relatively strong environmental regulations in the state, energy production is a high-ranking public need, and some long-established mining operations are not always subject to more recently established regulations or permitting requirements. Energy production and mining tend to be relatively localized threats, but they are significant to vernal-pool ecology where they occur (NHESP database). For example, some high-elevation vernal pools may be vulnerable to impacts from construction and maintenance of wind turbines on mountain ridges. Other vernal pools in and near utility rights-of-way may experience direct or indirect impacts from construction of new powerlines or pipelines. In both cases, there is potential for pool sedimentation, increased public access via off-road vehicles (see IUCN Threat 6), and loss of canopy cover.

IUCN Threat 4: Transportation and Service Corridors
Existing transportation and service infrastructure may indirectly impact vernal-pool habitat by limiting or reducing local biodiversity (Fahrig and Rytwinski 2009). Roads, highways, and railways often act as physical barriers to movement or as sources of adult mortality for organisms (e.g., salamanders, turtles) that use vernal pools and must traverse terrestrial habitat to access them (Gibbs 1998, Gibbs and Shriver 2005, Andrews et al. 2008, Bartoszek and Greenwald 2009, Sutherland et al. 2010). Roads and highways with high traffic volume also create noise pollution, which may alter breeding behavior (e.g., frog calling) in nearby pools in ways that either impair breeding activity (Tennessen et al. 2014) or result in certain tradeoffs that could conceivably reduce reproductive fitness (Parris et al. 2009, Cunnington and Fahrig 2010). In addition, transportation corridors are sources of chemical pollution for many vernal pools in Massachusetts, as storm runoff from roads and highways introduces metals, salts, oils, and other compounds to vernal pools, thus altering pool chemistry and, in some cases, impairing or destroying the biological function of the habitat (Turtle 2000, Croteau et al. 2008, Karraker et al. 2008, Brady 2012). Maintenance of service corridors (e.g., gas line and powerline rights-of-way) can alter vegetation composition and structure in vernal pools occurring within the corridors, or modify light conditions at pools bordering corridors; those types of impacts are generally considered relatively minor, however.

Development of new transportation and service corridors involves clearing, grading, or filling, which can result in direct filling and permanent physical loss of vernal pools. Blasting activities downslope of vernal pools can break perched water tables from below and thereby permanently destroy the hydrologic function of affected pool basins. Construction of roads and railroads near any wetland systems, including vernal pools, changes the natural flow or hydrology of local surface water and groundwater. Once established, transportation and service corridors threaten vernal-pool habitats as described in the preceding paragraph.

Certified Vernal Pools receive substantial regulatory protection from direct loss to development of new transportation and service corridors in Massachusetts. However, only a small percentage (less than 25%) of vernal pools in the state are currently recognized as CVPs. Some of the remaining vernal pools are protected from direct loss by local regulations, but not all municipalities have established such regulations, and those that have vary in their level of oversight and enforcement. Terrestrial habitats surrounding vernal pools are vulnerable to development of new transportation and service corridors, as there are few legal protections for those areas besides the MESA. There are few to no regulatory protections for vernal pools with respect to pollution from road and highway runoff, or with respect to the alteration of pool ecology caused by road-related animal mortality and habitat fragmentation.

The density of transportation and service corridors in Massachusetts is relatively high, and so the threat of development of new corridors is relatively low in most parts of the state. However, several proposed corridors may be highly ranked public needs, and some vernal pools may ultimately be lost or impaired as a result of their development. Pollution associated with road and highway runoff is a continuing concern for many vernal pools, and mortality of pool-dependent organisms attempting to cross roads is considered a major threat to pool ecology throughout much of the state.

IUCN Threat 5: Biological Resource Use
Some SGCN (e.g., Blanding's Turtle, Spotted Turtle) that use vernal pools are poached or otherwise collected. However, the magnitude of the problem and the degree to which vernal pools act as collection sites are unknown.

Timber harvesting (logging) is a common land use in most parts of Massachusetts (except for Cape Cod). Logging can impact vernal-pool ecology in a number of ways, not all of which are well understood (deMaynadier and Houlahan 2008). Logging removes portions of the forest canopy and therefore alters light conditions, water temperature, organic inputs, and nutrient cycling in and around vernal pools. Logging also compacts soils and may introduce nonnative invasive plants to the terrestrial habitat immediately surrounding vernal pools. Establishment of logging roads or trails adjacent to or through vernal pools can create problems with erosion and runoff, thus impacting water quality in pools. Overall, logging is considered a relatively minor threat to vernal pools in Massachusetts; other than the problem of nonnative invasive plants, logging-associated impacts to vernal pools are typically minor, temporary, or minimized by regulatory protections (e.g., the Forest Cutting Practices Act regulations [304 CMR 11.00]).

IUCN Threat 6: Human Intrusions and Disturbance
An unknown percentage of vernal pools in Massachusetts are impacted by human intrusions and disturbance. The most commonly observed disturbances are dumping, intentional filling, operation of off-road vehicles (ORVs), and biological surveys.

Dumping activity, as evidenced by the types of old cars and household appliances found in vernal pools, appears to be less substantial now than in decades past. However, dumping of trash, tires, brush, and lawn clippings is an ongoing threat to vernal pools located near roadside pull-offs, trailheads, and suburban yards. Intentional filling of vernal pools with tree limbs, leaves, and other yard waste by landowners attempting to manage surface water on or adjacent to their properties is an occasional problem. The degree to which dumping and filling impact vernal pools varies by locality, but smaller vernal pools in areas of greater human population density tend to be most at risk. While a small percentage of vernal pools are classified as CVPs and are therefore legally protected from dumping or filling, detection of violations and identification of violators can be difficult.

Operation of ORVs in vernal-pool basins is a common occurrence along electric transmission line rights-of-way and is a problem on some public lands in Massachusetts. Most such ORV use is illegal, and enforcement is difficult. Hence, chronic physical disturbance from ORV operation is a threat to vernal pools along most electrical transmission line corridors and on some public lands.

Vernal pools located on public lands are threatened by human disturbance via excessive biological surveying. There is high demand for public open space in Massachusetts, and some pools are surveyed multiple times per year for various recreational, educational, and/or scientific endeavors. Some types of surveys (e.g., log/rock-rolling, dip-netting) are disruptive to microhabitats within pools, while others (e.g., funnel-trapping) are disruptive to breeding activity of organisms using the pools. Repeated disturbance of vernal-pool basins appears most problematic on lands near large population centers (e.g., Boston, Springfield) and in areas where public land is in relatively short supply. The magnitude of the impacts to vernal-pool organisms has not been studied in Massachusetts, but physical alterations to pool microhabitats are apparent and could presumably harm their biological function. Human-caused spread of pathogens and disease among vernal pools is an additional threat to vernal-pool ecology.

IUCN Threat 7: Natural System Modifications
Abstraction of groundwater and surface water for residential, commercial, and agricultural use could potentially threaten vernal pools in Massachusetts. Substantial abstractions during droughty conditions (e.g., for residential and agricultural irrigation, commercial snow production) could contribute to low water tables and, therefore, shorten vernal-pool hydroperiods. This threat is underinvestigated in Massachusetts, and so its magnitude is unknown.

Classic vernal pools (small, completely isolated depressions that hold water seasonally) are vulnerable to flooding by beaver activity when they are located near streams and larger wetlands. As beaver dams are created and grow in size, substantial impoundments of water are created, engulfing nearby classic vernal pools and establishing a permanent hydroperiod. Most impoundments support populations of minnows, rendering the former vernal-pool area uninhabitable for smaller vernal-pool organisms (e.g., fairy shrimp). Some vernal-pool species, such as Spotted Salamander, can still use a beaver impoundment for the same purposes a former vernal pool had been used, but others, such as Jefferson Salamander and fairy shrimp, are far less flexible in their habitat requirements and may either disappear from the local system or exhibit significantly reduced numbers. After beavers abandon an impoundment and dams are breached, vernal pool basins may reappear. However, the cycle of beaver occupation, abandonment, draining, forest regrowth, and pool recolonization by vernal-pool organisms can be lengthy, playing out over many decades. In habitat patches isolated by roads and development, such temporary loss of vernal-pool habitat can have permanent impacts on local populations of pool-dependent organisms. Beaver activity is common and widespread in Massachusetts, but the magnitude of its threat to vernal-pool habitat is underinvestigated.

An unknown percentage of vernal pools in Massachusetts are vulnerable to filling via natural deposition and accumulation of organic matter, followed by plant succession. Small, shallow, heavily-shaded pools and acidic kettle holes seem most vulnerable. However, this phenomenon is understudied, and the magnitude of its threat to vernal pools in Massachusetts is unknown.

IUCN Threat 8: Invasive and Other Problematic Species and Genes

Emerging infectious disease is currently considered one of the greatest threats to global biodiversity, and amphibians are an especially vulnerable group. Although vernal-pool amphibians in the New England region appear to be relatively resistant to some pathogens that are problematic elsewhere in the world (e.g., the chytrid fungus *Batrachochytrium dendrobatidis* [*Bd*]; Longcore et al. 2007, Richards-Hrdlicka et al. 2013), there is suspicion that other pathogens, such as ranavirus, have caused recent mass-mortality events in the region's vernal pools (Wheelright et al. 2014), including Massachusetts pools that support SGCN. Of particularly grave concern is the potential for future introduction and spread of the salamander fungus *Batrachochytrium salamandrivorans* (*Bsal*), known best for its devastating impacts on amphibians in Europe (Martel et al. 2014).

The potential spread of pathogens among vernal pools may be facilitated by animal commerce, illegal animal translocations, use of contaminated field gear during biological surveys, and natural dispersal of native fauna (Picco and Collins 2008, Gray et al. 2009). Infection rates and long-term impacts to vernal pools and their associated organisms are understudied in Massachusetts. However, ranavirus is known to affect or be carried by a wide variety of taxa (e.g., frogs, salamanders, turtles, fish), and research findings in other parts of the country suggest that it can have severe, acute impacts on vernal-pool amphibians (Gray et al. 2009, USGS 2012, Brenes et al. 2014, Currylow et al. 2014). *Bd* is known to infect crayfish (Brannelly et al. 2015), and there is evidence that *Bd* causes reduced growth and increased mortality in certain species (McMahon et al. 2013). *Bd* could conceivably pose a threat to other vernal-pool crustaceans, including Intricate Fairy Shrimp, though this threat has not yet been assessed (to our knowledge). Given the great difficulty in controlling the spread of pathogens and the lack of knowledge about persistence and long-term consequences of local outbreaks, emerging infectious disease must be considered a major threat to vernal-pool ecology in Massachusetts.

The primary threat to plant SGCN (False Hop Sedge, Tuckerman's Sedge, Swamp Cottonwood) is competition from other tree and shrub species in the same habitat, and so introduction or proliferation of invasive plant species is a concern at certain vernal pools. The one population of Swamp Cottonwood known from Massachusetts may be a single clone, and so the potential for the species to colonize other vernal pools may be limited.

IUCN Threat 9: Pollution

Vernal pools are vulnerable to nutrient loading and chemical contamination when they are adjacent to lawns, golf courses, cropfields, parking lots, roads, gas stations, and other areas where accidental spills or deliberate applications of chemicals occur (Snodgrass et al. 2008). Surface runoff from those areas can introduce contaminants to vernal pools, thus altering water chemistry and impairing biological function (Burgett et al. 2007, Croteau et al. 2008, Baker et al. 2013). High-nutrient pollution washing into vernal pools from anthropogenic landscapes can lead to high growth of plant species, and may also encourage exotic invasive species to grow, outcompeting the native SGCN. CVPs and PVPs are sometimes afforded 100-ft terrestrial buffers (via the Massachusetts Wetlands

Protection Act and municipal bylaws, respectively) to mitigate the threat of contamination by runoff, but those regulatory protections do not apply to land uses that were in place prior to identification of a vernal pool and may not guard against infiltration of contaminated groundwater. Because of the high human population density in Massachusetts, some vernal pools are impacted by contamination via surface runoff (NHESP database).

The threat of road deicing salts to amphibian reproduction is of especially strong concern in New England (Turtle 2000, Karraker et al. 2008, Karraker and Gibbs 2011, Brady 2012). One aspect of deicing salts that is receiving increasing attention is the chemical component chloride. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). Chloride levels in groundwater appear to be increasing, thus feeding water with higher chloride levels into adjacent wetland systems. Many vernal pools are groundwater-fed, and so vernal-pool organisms would be vulnerable if chloride concentrations reach toxic levels.

Acidification of vernal pools is a concern for pool-dependent SGCN, especially amphibians. Low pH (lower than 4.5) can inhibit embryonic and larval development and survival, thereby reducing reproduction and recruitment (Freda and Taylor 1992, Karns 1992, Sadinski and Dunson 1992). Increases in acid precipitation may alter water chemistry in vernal pools slowly over time, or particularly heavy precipitation events may trigger sudden spikes in aluminum, which is toxic to larval amphibians (Jackson and Griffin 1991, Horne and Dunson 1995, Croteau et al. 2008). Anecdotal accounts of recent mass mortalities of larval amphibians in New England vernal pools seem to have some association with heavy rain events, though necropsies have not been performed. Plant SGCN associated with vernal pools in Massachusetts appear to inhabit pools with relatively higher pH; whether acidification of the pools would have a detrimental impact on those plant populations is not well understood.

Additional pollution-related threats to vernal pools in Massachusetts are described in IUCN Threat subsections 2, 4, 5, and 6.

IUCN Threat 10: Geological Events
There are no perceived threats to vernal pool habitats from geological events.

IUCN Threat 11: Climate Change and Severe Weather
Climate change analyses project varying scenarios for the northeastern United States. Although total precipitation is expected to increase, other common predictions include warmer temperatures, longer and more severe summer droughts, shorter but more intense winter/spring floods, and reduced extent and duration of winter snow cover. Taken together, such changes could dramatically alter the hydroperiods of many vernal pools in the region, thereby posing significant threats to their dependent organisms.

For example, vernal pools may, on average, fill with water later in the fall or winter, and dry earlier in the spring or summer. Later pool filling and earlier pool drying could disrupt the reproductive ecology of Marbled Salamanders in Massachusetts. Females of this species normally oviposit in early to mid-September and brood their eggs until early or mid-October, or until the pool basin fills with water (whichever comes sooner). When basins remain dry into October, freezing or near-freezing nighttime temperatures are one suspected reason for females to abandon nests; other contributing factors might be dehydration and prolonged vulnerability to predation. If climate change causes basins to fill later, and Marbled Salamanders do not adjust the onset of breeding accordingly, then a reduction in the presumed benefits of egg-brooding would be expected, as eggs would be left unattended for longer periods of time and might incur reduced hatching success. Earlier drying of pool basins in the spring would be expected to result in greater larval mortality and reduced juvenile recruitment. In addition, a generally shorter pool hydroperiod (late filling, early drying) could limit larval growth and, therefore, reduce juvenile fitness. Similarly, earlier pool drying without a simultaneous adaptation by spring-breeding amphibians to breed earlier in the spring would result in increased larval mortality, reduced larval growth, or reduced juvenile fitness.

Increased frequency of severe weather, as predicted by some climate-change scenarios, would likely make vernal pool hydrology and chemistry far less stable. Sudden or dramatic changes in water chemistry (e.g., temperature, pH, salinity) would be expected to increase physiological stress for vernal-pool organisms and directly and indirectly reduce reproductive success and survival.

Climate change is expected to have some level of impact on virtually all vernal pools in Massachusetts. However, hydrological and biological function is most threatened in vernal pools that are relatively small, relatively shallow, and/or occur at higher elevations.

Conservation Actions

Direct Management of Natural Resources
Improve reproductive opportunities for vernal pool SGCN by constructing vernal-pool basins. Several pool-construction projects to benefit Eastern Spadefoot have been undertaken in recent years, and further work to determine successes and troubleshoot shortcomings is planned. Those projects have focused on sites with significant agricultural activity and a history of breeding-pool loss, as well as potential reintroduction sites. Construction of vernal pools for Jefferson Salamander seems to be a viable conservation strategy, given the species' habit of colonizing abandoned farm ponds, and other man-made impoundments. Creation of vernal pool basins for Blue-spotted Salamander and Marbled Salamander still requires development of proven engineering. Other vernal pool SGCN would be expected to benefit incidentally from pools designed for these amphibians. Although breeding-pool creation for salamanders in Massachusetts is not a high conservation priority, pool construction would be beneficial in areas where breeding habitat is a limiting resource, especially on protected lands.

Data Collection and Analysis
Conduct targeted biological surveys of known and potential vernal pools for SGCN, using invasive-species BMPs to control the potential spread of infectious diseases. Biological inventory and monitoring of vernal pools is necessary to identify and understand distribution and abundance of vernal pool SGCN. Data generated by such surveys are critical to establishing and maintaining site-specific regulatory protections for SGCN and to developing effective, long-term conservation plans for the species. For example, all populations of False Hop Sedge likely occur in certifiable vernal pools, but not all such pools supporting the plant have been certified.

Develop and implement a long-term, statewide, vernal-pool monitoring program. Long-term monitoring of vernal-pool hydrology, chemistry, pathogen loads, and associated SGCN demographics is needed to detect, understand, and act on SGCN population trends at both local and state scales. Such a program would be especially beneficial in understanding and planning for impacts associated with climate change, emerging infectious disease, pollution, and habitat loss or fragmentation.

Conduct species-specific research at vernal pools to fill data gaps associated with SGCN life history, habitat requirements, population ecology, sampling techniques, and other subjects. Vernal pools function as population centers for several SGCN and are natural sites for studying fundamental aspects of the species and improving our knowledge about how to study them more effectively. Investigations into population genetics, microhabitat preferences, metapopulation dynamics, and survey efficacy are examples of research that will help inform conservation planning and associated actions. One priority is to work with conservation partners to improve our understanding of the genetic structure of salamander populations in the Jefferson/Blue-spotted salamander complex. Preliminary findings from an earlier study suggest that such work could play a major role in prioritizing sites for conservation. Another priority is to investigate whether the single known Swamp Cottonwood population in Massachusetts consists of all one sex, or if seed reproduction is possible.

Education and Outreach
Promote vernal-pool certification in Massachusetts. One of the most effective means of protecting vernal-pool basins from direct loss is to have them certified as vernal-pool habitat under the Massachusetts Wetlands Protection Act. Promotion of the certification program is an effective way to involve the public in hands-on stewardship of the environment, and the certification process involves participants in ways that educate them about vernal-pool habitats, their functions, and their value to SGCN and local biodiversity. Promotional tools may include development of websites, social

media campaigns, listserv announcements, and workshops.

Produce and provide educational products, services, and opportunities to the Massachusetts public regarding vernal-pool ecology and conservation. Keeping the public knowledgeable about vernal-pool ecology and the importance of vernal pools to SGCN and general biodiversity is prerequisite to raising awareness of conservation needs. Providing educational services and opportunities for hands-on experience are key ways to keep the public interested and active in vernal-pool conservation. Together, those actions should help foster public support for vernal-pool research, regulatory protections, and conservation initiatives. Products, services, and opportunities may include vernal-pool publications, website development, technical support for vernal-pool certification, technical support for school studies/programs, coordination of citizen-science projects, public presentations, and inclusion of individuals in the NHESP's biological survey work.

Harvest and Trade Management
See the Law Enforcement and Law and Policy sections, below.

Land and Water Rights Acquisition and Protection
Develop and maintain a list of vernal pools that should be considered priorities in land protection for SGCN. The NHESP *BioMap2* project prioritized coarse-filter areas statewide for potential land-protection efforts, and some of those areas were based on occurrences of Potential Vernal Pools. However, additional work is needed to identify specific vernal pools that rank especially high in their perceived value to SGCN and should be actively pursued in land acquisition and protection efforts. Some of the Data Collection and Analysis actions described above are designed to inform land protection.

Law Enforcement
Continue to implement legal mandates of the MESA (M.G.L. c. 131A) and regulations (321 CMR 10.00). The NHESP regulates environmental impacts to vernal pools where they are known to function as habitat for SGCN listed as Endangered, Threatened, or Special Concern pursuant to the MESA. Published delineations of Priority Habitat for those species define specific geographic areas where most types of proposed land, water, or vegetation alterations are required to be reviewed and approved in advance by the NHESP. The review process can involve adjustment of project plans to avoid or minimize impacts to vernal pools and their associated MESA-listed SGCN, or require mitigation of impacts that are deemed unavoidable. The MESA also provides for criminal and civil penalties for any unauthorized "take" of MESA-listed SGCN.

Enforce other laws that protect SGCN associated with vernal pools. Hunting regulations (321 CMR 3.05) prohibit disturbance, harassment, or other taking of SGCN associated with vernal pools, such as Blue-spotted Salamander, Jefferson Salamander, Marbled Salamander, Eastern Spadefoot, Northern Leopard Frog, Blanding's Turtle, and Spotted Turtle.

Continue to provide technical support for implementation of other laws protecting vernal pools and associated SGCN. The NHESP provides technical support to conservation commissions and the Massachusetts Department of Environmental Protection regarding their implementation of state-listed rare species and vernal-pool protection provisions of the Massachusetts Wetland Protection Act.

Law and Policy
Develop or update regulations and policies as necessary to address emerging threats. Needs to adopt new regulations or policies may arise as knowledge is gained about climate change, emerging infectious disease, animal trade, and other threats.

Planning
Develop and maintain lists of vernal pools that should be considered priorities in future biological surveys for SGCN. The discovery of undocumented local populations of SGCN is a conservation priority. Additional priorities include identification of all vernal pools currently used by a given local population of SGCN (e.g., in a metapopulation of Marbled Salamander) and an evaluation of the relative importance of each pool to the population. Biological survey continues to be a cornerstone of the conservation strategy for vernal-pool SGCN, as the data generated are invaluable to informing other types of conservation actions. Identification and prioritization of prospective survey sites is an essential planning activity to maximize survey efficacy.

Develop detailed conservation and recovery plans for SGCN associated with vernal pools. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on vernal pool SGCN populations.

Develop strategies for stabilizing regulatory Priority Habitat maps as they pertain to vernal-pool SGCN. As one conservation strategy for species listed pursuant to the MESA, the NHESP delineates Priority Habitat as a screening tool to regulate certain projects involving habitat alterations (see Law Enforcement above). Priority Habitat maps are updated periodically to reflect new information about the occurrences of state-listed rare species, but the magnitude of changes in the maps from one cycle to the next can create a number of challenges that reduce the efficacy of the strategy. This problem is applicable to SGCN in many habitats, and there is a need to develop strategies for increasing the long-term stability of delineated habitat footprints. At minimum, the process will need to account for long-range population objectives and biological inventory demands, and it will need to complement other conservation strategies effectively. This approach to increasing stability of the regulatory footprint provides an opportunity to forge a closer connection between regulation, on the one hand, and proactive conservation planning and implementation, on the other.

Species Reintroduction and Stocking

Conduct species introduction or reintroduction projects with vernal pools as release sites. Translocations of vernal-pool SGCN to new sites or to sites of historical occurrence is a developing conservation strategy in Massachusetts. For example, a project to reintroduce Eastern Spadefoot to a site in the southeastern part of the state was initiated by conservation partners several years ago. The project involved the construction of multiple vernal pools, captive rearing of tadpoles, and translocation of tadpoles and metamorphs to the pools. A second pool-creation project for Eastern Spadefoot initiated by the NHESP in the past year may ultimately involve stocking of the pool with translocated eggs or tadpoles. If these projects are successful, selective reintroduction and stocking may grow as a conservation tool and involve additional vernal-pool SGCN. The approach could prove to be an effective way to reestablish local populations where only the organisms have been lost but the habitat remains, as might occur with episodic disease outbreaks.

Coastal Plain Ponds

Habitat Description

Coastal plain ponds are shallow, naturally low-nutrient, and highly acidic ponds in sandy glacial outwash, usually with no inlet or outlet. Most of the coastal plain ponds in Massachusetts contain permanent water, but some are shallow basins where groundwater drops below the surface late in the growing season. Water rises and falls with changes in the water table, typically leaving an exposed shoreline in late summer, though in wet years the pondshore may remain inundated. The dominant plants on the shore exposed as the water level drops are herbaceous and graminoid species. The pond substrate varies from sand-cobble to muck.

New England's coastal plain ponds are primarily located in southeastern Massachusetts and Rhode Island (Sorrie 1994). In Massachusetts, coastal plain ponds are limited to the southeastern part of the state, with some similar ponds on sand or gravel in the lower Connecticut Valley. In preparing for a study (Corcoran 2002) on coastal plain pondshores, the NHESP identified 329 ponds with potential coastal plain pondshore communities. That study and subsequent work have identified only 11 pondshore occurrences considered to be in excellent condition (having an "A" rank). All but three of the A-ranked ponds are in conservation ownership. In 2015, NHESP has 120 coastal plain pondshore occurrences considered to be viable in the long term (ranked A-C) in its database. The main reason for the lower ranking of the coastal plain ponds was the presence of a zone of contribution to a public water supply well, which alters the natural hydrologic fluctuations that the ponds depend on for viability.

Most coastal plain ponds in Massachusetts have no natural streams flowing in or out, although since European settlement some have been connected to other wetlands, especially to function as reservoirs for cranberry bogs. The hydrological dynamics of coastal plain ponds are governed by groundwater and precipitation, with some ponds having a high degree of influence from groundwater. While some are almost exclusively dependent on precipitation, most are characterized by combinations of groundwater and precipitation. The bottoms of the ponds consist of variably deep organic material that inhibits the movement of water. Along the upper sandy shore, water movement is not as restricted, and there are active, direct connections between the pond and the groundwater. In the winter, when there is little evaporation and much precipitation, the groundwater and ponds rise, and the ponds are recharged. During leaf-out in the spring, trees increase transpiration, evaporation increases from leaves and pond surfaces, and water levels recede, lowering pond levels. Groundwater connections provide cool, low-nutrient water to ponds, and would normally enhance water quality. In areas with polluted groundwater, however, ponds can acquire the pollutants, with negative effects on the habitat.

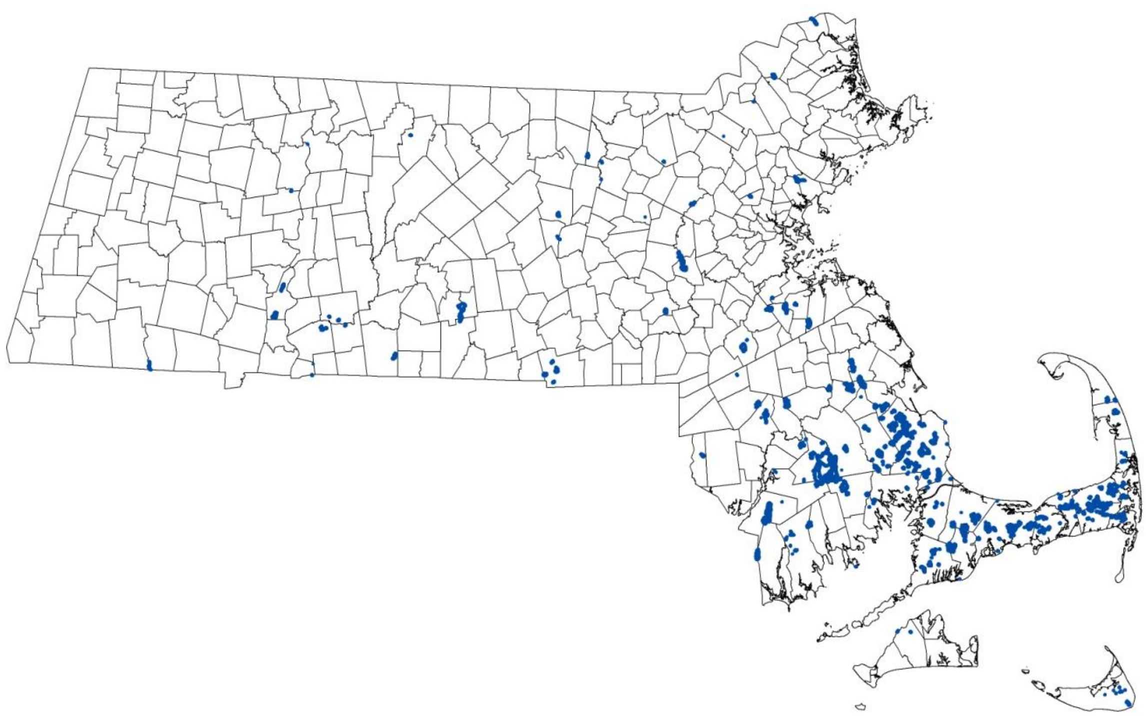


Figure 4-34: Coastal Plain Pondshores and Locations of Coastal Plain Pond Species in Massachusetts.

Species of Greatest Conservation Need in Coastal Plain Ponds

Forty SGCN are assigned to the Coastal Plain Pond habitat (Table 4-27).

Coastal plain ponds and pondshores provide habitat for many species that occur almost exclusively on coastal plain ponds. The plants of the pondshore community are particularly adapted to the nutrient-poor conditions, and although often restricted to that environment, are able to compete with more widespread plants that require more nutrients. The periodic inundations of the shore help to keep out shrubs and upland plants, and the periodic drying keeps out the obligate aquatic plants. Coastal plain pondshores are important habitat for dragonflies and damselflies (over 45 species are known to occur on coastal plain ponds and several of those species are rare). Further, coastal plain ponds have been listed by others as the most vulnerable odonate habitats in the northeastern United States (White et al. 2014). They are also important habitat for Painted, Musk, Spotted, and Snapping Turtles, and for the federally Endangered Northern Red-Bellied Cooters. Larger ponds and pondshores are used by migrating and wintering waterfowl, including Common and Hooded Mergansers, Goldeneye, and Bufflehead. Some of these ponds support warmwater fish and freshwater mussels. Coastal plain ponds can function as vernal pools when fish populations are absent.

When fish are present through historical introductions or hydrologic connectivity with other waterbodies, freshwater mussels may also be present and play an important ecological role in nutrient cycling of coastal plain ponds. Species likely to occur include the MESA-listed Eastern Pondmussel (*Ligumia nasuta*) and Tidewater Mucket (*Leptodea ochracea*), and the unlisted Eastern Lampmussel (*Lampsilis radiata*) and Triangle Floater (*Alasmidonta undulata*).

Exposed pondshores also provide habitat for turtle nests. Near-shore emergent plants are important sites for dragonflies and damselflies, some of which oviposit in the stems. Many odonates live amongst the submerged vegetation as larvae and climb onto the emergent vegetation to undergo metamorphosis to adults.

There are several plant species that occur only in coastal plain ponds**,** including the globally rare species Plymouth Gentian, Rose Coreopsis, Terete Arrowhead, and Creeping St. John's-wort (see Table 4-27, above). Many of the rare plant species associated with coastal plain ponds are regionally rare species as well, as indicated by Brumback and Gerke (2013).

The plants of the community appear to form zones dependent on the magnitude, duration, frequency, and timing of flooding and exposure events between the water and the shrubs around the pond. Of the SGCN plants, New England Boneset, Maryland Meadow-beauty, and Pondshore and Swamp smartweeds occur in the driest zone, inundated only during high-water periods. An intermediate area of beach provides habitat for most of the species of the coastal plain pondshore community; the globally restricted but locally abundant Plymouth Gentian and Rose Coreopsis grow in this zone. In the submerged or water-saturated areas, Terete Arrowhead, Subulate Bladderwort, and the Horned- and Bald-sedges may occur.

Table 4-27: Species of Greatest Conservation Need in Coastal Plain Ponds

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Pseudemys rubriventris*	Northern Red-bellied Cooter
Mussels	*Alasmidonta undulata*	Triangle Floater
	Anodonta implicata	Alewife Floater
	Lampsilis radiata	Eastern Lampmussel
	Leptodea ochracea	Tidewater Mucket
	Ligumia nasuta	Eastern Pondmussel
Odonates	*Rhionaeschna mutata*	Spatterdock Darner
	Anax longipes	Comet Darner
	Enallagma pictum	Scarlet Bluet
	Enallagma recurvatum	Pine Barrens Bluet
Plants	*Amphicarpum amphicarpon*	Annual Peanutgrass
	Carex striata	Walter's Sedge
	Coleataenia longifolia ssp. *longifolia*	Long-leaved Panic-grass
	Coreopsis rosea	Rose Coreopsis
	Dichanthelium dichotomum ssp. *mattamuskeetense*	Mattamuskeet Panic-grass
	Dichanthelium wrightianum	Wright's Panic-grass
	Eleocharis microcarpa var. *filiculmis*	Tiny-fruited Spike-sedge
	Eleocharis tricostata	Three-angled Spike-sedge

Taxon Grouping	Scientific Name	Common Name
	Eupatorium novae-angliae	New England Boneset
	Hypericum adpressum	Creeping St. John's-wort
	Isoetes acadiensis	Acadian Quillwort
	Isoetes lacustris	Lake Quillwort
	Juncus debilis	Weak Rush
	Lachnanthes caroliniana	Redroot
	Lipocarpha micrantha	Dwarf Bulrush
	Ludwigia sphaerocarpa	Round-fruited Seedbox
	Panicum philadelphicum ssp. *philadelphicum*	Philadelphia Panic-grass
	Persicaria puritanorum	Pondshore Smartweed
	Persicaria setacea	Swamp Smartweed
	Rhexia mariana	Maryland Meadow-beauty
	Rhynchospora inundata	Inundated Horned-sedge
	Rhynchospora nitens	Short-beaked Bald-sedge
	Rhynchospora scirpoides	Long-beaked Bald-sedge
	Rhynchospora torreyana	Torrey's Beak-sedge
	Rotala ramosior	Toothcup
	Sabatia campanulata	Slender Marsh Pink
	Sabatia kennedyana	Plymouth Gentian
	Sabatia stellaris	Sea Pink
	Sagittaria teres	Terete Arrowhead
	Utricularia subulata	Subulate Bladderwort

Threats to Coastal Plain Ponds

IUCN Threat 1: Residential and Commercial Development
High-nutrient leachate from nearby improperly maintained septic systems poses the long-term threat of pond eutrophication on these naturally low-nutrient ponds. The shoreline communities are threatened by clearing, planting, and mowing of lawns, and other activities associated with both residential and commercial development. Municipal wells and other water withdrawals from the areas of the ponds strongly affect water levels in the ponds and the natural fluctuations to which native species are adapted. Residential development was also listed as a significant threat to Red-bellied Cooters in the recovery plan prepared by USFWS (1994). Conversion of the landscape to impervious surface alters the natural hydrology of coastal plain ponds and increases runoff of contaminants into the surface and groundwater.

IUCN Threat 2: Agriculture and Aquaculture
Use of coastal plain ponds as recipients of irrigation runoff from cranberry bogs introduces nutrients and pesticides into the water, as well as changing the natural fluctuations of water levels and changing the dynamics of the shore lines. The nutrients and pesticides can alter which species can survive in the ponds and on the pondshores, and encourage excessive growth of algae and vascular plants.

IUCN Threat 3: Energy Production and Mining
At least one pondshore is said to have had peat mining in the past, which changed the shoreline and pond contours. Gravel pits and municipal water wells in the vicinity of coastal plain ponds can affect the groundwater flow and thus the water levels and fluctuations.

IUCN Threat 4: Transportation and Service Corridors
Roads and railroads near any wetland systems, including coastal plain ponds, change the flow of surface and groundwater. The subsurface compaction necessary for both roads and railroads alters groundwater flow. With roads comes an increase in road salt, and its associated components, chloride in particular. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the

chloride levels in the groundwater are slowly increasing over time, feeding water with higher levels of chloride into adjacent wetland systems, threatening these ecosystems with this chemical, which is toxic at high concentrations.

Overhead transmission line rights-of-way are kept clear of trees, changing the rate of evapotranspiration of the coastal plain ponds. The lack of trees may benefit the rare species that prefer the open habitat, but will also increase the warming of the water within the pond. Rights-of-way may also become off-road-vehicle paths, allowing additional access for vehicles to pondshores and potentially resulting in damage to pondshores and exposed pond bottoms.

IUCN Threat 5: Biological Resource Use
Nonnative fish are often stocked in coastal plain ponds (Sorrie 1994), though the influences of introduced fish on pond ecology are unknown. Some visitors use off-road vehicles to access the coastal plain pond habitats and drive along the shorelines, threatening and damaging the shoreline vegetation, including the SGCN plants and turtle nests located in this zone.

IUCN Threat 6: Human Intrusions and Disturbance
Emergent plants that are part of normal pond vegetation, or are enhanced by extra nutrients, can be perceived as a problem for human recreation; they are sometimes removed to enhance recreational activities (swimming). Such emergent plants are important parts of the habitat of native fauna, providing cover for waterfowl nests, perches for other birds, and sites for odonates to emerge.

Further, the activities related to shoreline development and recreation in lakes and ponds can affect habitat of rare mussels and odonates. Nedeau & Johnson (2009) examined the effect of docks on freshwater mussels in southeastern Massachusetts ponds. While there was no correlation between the presence of docks and absence of rare mussels, there were significantly fewer rare mussels in areas of developed shorelines than undeveloped shorelines. Effects of the shoreline development (e.g., runoff) could not be separated from the level of recreational activity that occurs in areas of developed shoreline. Large numbers of human swimmers can have the same effect by increasing nutrients in the water and trampling or removing aquatic and shoreline plants. Vehicle use on pondshores during low water may destroy the vegetation.

IUCN Threat 7: Natural System Modifications
Many coastal plain ponds are in a fragile balance. Municipal and irrigation well withdrawals can lower water levels within the pond dramatically, allowing the expansion of shrubs into the historical open-bank area of the pond. However, there is also a concern with rising groundwater levels due to climate change (see Climate Change below), which leads to higher than normal water levels, preventing the natural water-level cycling in the ponds.

Alterations to natural flow regimes pose the greatest threats to these systems. Shrub and tree encroachment threaten pondshores in areas with excessive withdrawal. Seasonally high water levels prevent tree and shrub encroachment, and seasonal low water is necessary to expose the pondshore for plant germination and growth. Excessive drawdown from pumping for water consumption reduces natural fluctuations and allows woody species to advance down the shores.

However, some ponds under the influence of withdrawal for more than 100 years have supported globally rare plant populations. When ponds were allowed to return to natural flow regimes, these populations vanished. Thus, it is the sudden *change* in hydrology that may have negative impacts on the plants of coastal plain pondshores.

McHorney and Neill (2007) demonstrated a distinct connection between some coastal plain ponds and groundwater. The DFW and other conservation entities have made a concerted effort over the past several years to identify top-quality ponds, and to protect them through acquisition and regulation. Acquisition funds from several of the last few open space bonds have been used to acquire some relatively undisturbed ponds in Plymouth and Barnstable counties. The need for clean water sometimes leads water companies or water districts to view conservation areas as ideal locations for public water supplies, without considering impacts to wetland dynamics when issuing water supply permits.

Very few of the ponds have naturally low water levels that leave the bottom of the ponds without standing water, although some of the ponds near large wells have been drawn down completely in recent years. Dragonfly and damselfly larvae live in water among aquatic vegetation. Eggs and larvae may survive for a time either in the stalks of vegetation (where many species lay their eggs) or in the mud of drying ponds. Fortunately they disperse relatively well, and with nearby sources of odonates, a temporarily drawn-down pond can have its insect life restored. If all ponds in an area are drawn down too often, that restocking is less likely. Frogs and turtles may be able to survive by moving to wet ponds, or digging into the drying mud. Again, survival depends on not having this occur too often, or over too large an area. As the water levels go down, any aquatic organic material is subjected to oxidation and removal from the system, changing the water-holding capacity of the pond's substrate, and possibly making the pond more vulnerable to water drawdowns in the future.

IUCN Threat 8: Invasive and Other Problematic Species and Genes

As nonmigratory goose populations have grown, besides enriching the waters of the ponds they live on, they graze the plants along the shores, sometimes in such numbers as to change the proportions of different species and the resultant habitat for other animals.

Common Reed, *Phragmites australis* var. *australis*, is a plant that colonizes disturbed areas and, once established, is very difficult to eliminate. Fortunately, it now occurs in only a few of the coastal plain ponds. Where it does occur, it can completely dominate the habitat. It also changes the habitat by increasing transpiration rates. Another exotic invasive species that has recently invaded Coastal Plain Ponds is Gray Willow (actually a complex of species that includes *Salix cinerea*, *S. atrocinerea,* and probable hybrids). This species complex is not as averse to seasonally high water as native shrubs are, and seems to thrive along these pond shores, particularly where soil disturbance has occurred. Both Fanwort (*Cabomba caroliniana*) and Hydrilla (*Hydrilla verticillata*) are increasingly detected in coastal plain ponds and control of these species is very difficult. Further, the control of nuisance aquatic plants, particularly submerged aquatic vegetation, often requires the use of herbicides at concentrations that may have unintended effects on local populations of rare native plants and animals (further assessed in IUCN Threat 9: Pollution).

Cyanobacteria blooms are becoming more prevalent in Massachusetts lakes and ponds, and have been associated with freshwater mussel kills. The underlying mechanism of mortality is not known, but several factors may be involved, either together or singularly: 1) algal blooms may reduce dissolved oxygen concentrations leading to acute hypoxia and mussel death (Strayer 2013); 2) as the algal communities in a pond shift from green algae to cyanobacteria, decreased nutritional value may cause a sustained decline in mussel health (Gelinas et al. 2013); and 3) accumulation of cyanotoxins by the mussel results in physiological toxicity and decline in mussel health (Travers et al. 2011).

IUCN Threat 9: Pollution

High-nutrient leachate from improperly maintained septic systems poses the long-term threat of pond eutrophication. Atmospheric deposition of nitrogen is changing water chemistry regionally (DOI 2014). Previous land-use practices, particularly agriculture, have left a legacy of excessive phosphorus reservoirs in several coastal plain ponds. Algal blooms resulting from phosphorus and nitrogen availability have resulted in rapid growth of periphyton and phytoplankton (Kniffin et al. 2009). This eutrophication can result in reduction or extirpation of freshwater fish and mussel populations (Nedeau 2011).

Overwintering populations of Canada geese may provide sufficient nutrient enrichment to result in overgrowth of algae and nonnative plants, reducing the habitat available to the rare native plants of the pondshore community.

Another source of potential pollution is pesticides entering coastal plain ponds from nearby cranberry bogs, and those used to treat nuisance aquatic plants. Agricultural runoff, pesticides, and use of herbicides to control nuisance aquatic plants further threaten aquatic systems, as aquatic invertebrates, and mussels in particular, are significantly more sensitive to toxicity from herbicides used in agriculture and nuisance aquatic plant management (Milam et al. 2005, Bringolf et al. 2007, Archambault et al. 2014). Further, many of the herbicides used to control aquatic nuisance plants are not specific enough to be protective of sensitive native fauna (Mattson et al. 2004).

IUCN Threat 10: Geological Events

These are not a particular threat to coastal plain pond habitats.

IUCN Threat 11: Climate Change and Severe Weather

Climate change and severe weather may threaten these habitats. As no one can predict exactly what form climate change may take, several possible situations are discussed. Warmer temperatures will warm water in coastal plain ponds faster than normal, and may make some ponds inhospitable to their current suite of species. Warming of surface and groundwater in coastal plain ponds may create conditions that favor invasive species, and increase growing seasons for harmful algal blooms. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms.

Recent research indicates that the last two decades have been the wettest years in the Northeast in 500 years (Pederson et al. 2013, Newby et al. 2014, Weider and Boutt 2010). Pondshores not under the influence of water withdrawal did not experience pondshore exposure for ten years, which has led to the loss of plant populations from several ponds.

Due to sea-level rise, groundwater levels have risen 6 inches in southeastern Massachusetts since 1970 (USGS 2014). The influence of increasing rates of sea-level rise will be examined in a forthcoming USGS study. These observations suggest that changing weather patterns, possibly linked to climate change, could alter the patterns of water level fluctuation in these ponds, posing a potentially significant long-term threat.

The cumulative impacts of increasing nonporous surfaces and climate change have been implicated in rising temperatures in an aquifer (Eggleston & McCoy 2015). Rising groundwater temperatures would have several implications for pond ecology, including flow rates and metabolism changes.

Conservation Actions

Direct Management of Natural Resources
Adaptive water-withdrawal management to allow maintenance of historical hydrodynamics to offset effects of climate change may be warranted.

Work with the USGS, DEP, town water departments and possibly cranberry bog operators on experimental manipulation of water levels to maintain the coastal plain pondshore, within an adaptive management framework.

Conduct pilot management of water levels at Cooks Pond WMA to restore pondshore plant community, including a population of globally rare New England Boneset and other SGCN plants that occur or occurred at this site. If successful, identify other prospective coastal plain ponds where species restoration could be completed and managed appropriately.

Work with DCR, the Town of Plymouth, and other partners to manage Gray Willow and other invasive species at priority coastal plain pond sites.

Data Collection and Analysis
The Sustainable Water Management Initiative, administered by DEP, with input from multiple state agencies, is supporting research by USGS into the degree of hydrological alterations imposed by water supply withdrawals and climate change. This effort is in the design stage and expected to be implemented in 2015.

Continue ongoing field surveys of possible coastal plain ponds, to supplement the report produced in 2002. Continue to work with various conservation partners in southeastern Massachusetts, Cape Cod, and the Islands in this effort.

Develop long-term-monitoring protocols to assess changes to pondshore communities and hydrodynamics over time.

Continue a multi-year study in partnership with USFWS to evaluate the efficacy of headstarting and to assess the current statewide population of federally endangered Red-bellied Cooters. The Cooter headstarting program has been implemented for more than 25 years, and is believed to be the largest and longest-running program of its kind. Preliminary field work and data analysis suggests that headstarted turtles can experience very high survivorship to adulthood and are reproducing successfully in the wild. As a result, research to quantify the effectiveness of the program and assess progress towards recovery of the population is a high priority.

Continue to monitor aquatic communities and habitats in a structured approach that will be useful to assess relationships between impervious surface, water quality, and assemblage integrity.

Continue to track occurrences of invasive invertebrates during native species surveys. Encourage data reporting from other agencies, consultants, and academics. Coordinate with other state environmental agencies, nonprofit groups, and citizen science organizations to monitor water quality parameters in coastal plain ponds. Coordinate research on the effects of harmful algal blooms on rare aquatic fauna.

Education and Outreach
Educate and inform the public about the values of coastal plain ponds and the issues related to their conservation, through agency publications and other forms of public outreach, in order to instill public appreciation and understanding.

Continue to work with schools and volunteers on the Red-bellied Cooter headstarting program.

Continue working with the Southeastern Massachusetts Pine Barrens Alliance to increase awareness of all the community and species resources in their area of interest (Southeast and Cape), including coastal plain ponds.

Work with other state agencies to define invasives of greatest risk and collaborate as needed to find funding for research and conservation action for species that pose greatest threat. Collaborate with stakeholders, municipalities, DEP, DCR, and DPH to identify best management practices for control of harmful algal blooms to aid in protection of rare aquatic fauna.

Coordinate with other state agencies and municipalities to reduce inputs of nutrients, sediments, and organic pollutants to state waterbodies. Continue to work with DEP, using established risk assessment approaches, to devise performance standards for aquatic herbicide use protective of freshwater mussels and other aquatic invertebrates.

Posters and booklets (similar to one produced in 1999 by DFW and the Wildlands Trust of Southeastern Massachusetts) could be put on the DFW website for the public to access.

Harvest and Trade Management
Consider instituting managed hunts for Canada Geese on coastal plain ponds where large numbers of geese threaten rare plants and nutrient balance.

Land and Water Rights Acquisition and Protection
Protect land around coastal plain ponds supporting populations of animal and plant SGCN, particularly around exemplary coastal plain ponds.

Law Enforcement
Regulate and limit the impacts of development, nutrients, and water withdrawals on coastal plain ponds.

Enforce off-road vehicle prohibitions on pondshores to reduce damage to habitats and wetlands.

Encourage the local conservation commissions to enforce the Wetlands Protection Act and town and regional bylaws restricting work in coastal plain ponds and the 100-foot buffer zones surrounding them.

Law and Policy
DFW will continue to review proposed development projects within priority habitat of MESA-listed species.

Application of the results of the USGS study to water supply regulation and withdrawal permits could greatly reduce the impacts of water supply withdrawal on these systems.

Coordinate with DCR to include new invasive species on the formal list of Aquatic Invasive Species for regulatory inclusion under the Act to Protect Lakes and Ponds and DCR Regulations under the Aquatic Nuisance Control Program (302 CMR 18.00).

Planning
Develop detailed conservation and recovery plans for SGCN associated with coastal plain ponds. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations. An integrated plan for coastal plain ponds, focusing on

protection, regulation, research, monitoring, management, and education, is recommended.

Continue efforts to prioritize and rank coastal plain pondshores and to develop site-specific management plans for priority sites.

Review the potential to restore SGCN to permanently protected coastal plain ponds.

Species Reintroduction and Stocking
Populations imperiled by climate change should be evaluated to determine if translocation is recommended.

The Department of Fish and Game now owns Cooks Pond in its entirety and acquired the water rights previously held by a cranberry operation. This pond previously supported a New England endemic plant species which has not been observed at this pond since 1988. A management plan is being developed for the pond, and a reintroduction of the species is proposed from seed gathered from an adjacent coastal plain pond.

Continue implementation of the Northern Red-bellied Cooter headstarting program.

Springs, Caves, and Mines

Habitat Description

Springs are formed when groundwater surfaces. They are found throughout the state in unconsolidated glacial deposits. In Berkshire County, springs and solutional caverns are formed in extensive marble and dolomite rock formations, forming a complex elevated karst terrain. Caves are formed primarily by overhanging rock ledge and in spaces among the rocks of talus slopes. Caverns, as compared to caves, are formed when groundwater dissolves carbonate bedrock. Air temperature in caverns approximates the mean annual temperature of the county and varies according to the caverns' natural ventilation. Air and water temperatures in karst systems are relatively stable, allowing species to have persisted perhaps even through glaciation events (Peck 1998).

Some of the taxa associated with karst systems may be hundreds of millions of years in age. Food sources are relatively sparse in groundwater systems, though organic materials are brought into karst systems by surface waters and fissures. As a result, groundwater foodwebs are less complex and less diverse than epigean systems. Hypogean fauna are classified based upon their degree of reliance on groundwater. Stygophiles use groundwater habitats, but are not groundwater obligates, and stygobites are completely dependent on groundwater habitats (Gibert 1994). With no affinity for groundwater, the stygoxenes are accidentally present and provide important nutrients to stygophiles and stygobites. The transition zone between groundwater and surface waters is called the hyporheic zone. Recognition of this zone has led to increased understanding of the geochemical and ecological interactions between groundwaters and surface waters (Gibert 1997).

There are more than 70 documented caverns in Massachusetts and an unknown number of caves. None of these hypogean habitats in Massachusetts, despite great potential for supporting undescribed endemic animals, have been surveyed for these animals sufficiently. There are two thermal springs in the northwest corner of the state, one on unprotected land and the other developed as a bottled-water plant.

Abandoned mines in Massachusetts can also serve as a kind of cave or cavern habitat, particularly for hibernating bats. Most of the larger abandoned mines in the state have been surveyed for hibernating bats, but few have been checked for other spring, cave, or cavern animals.

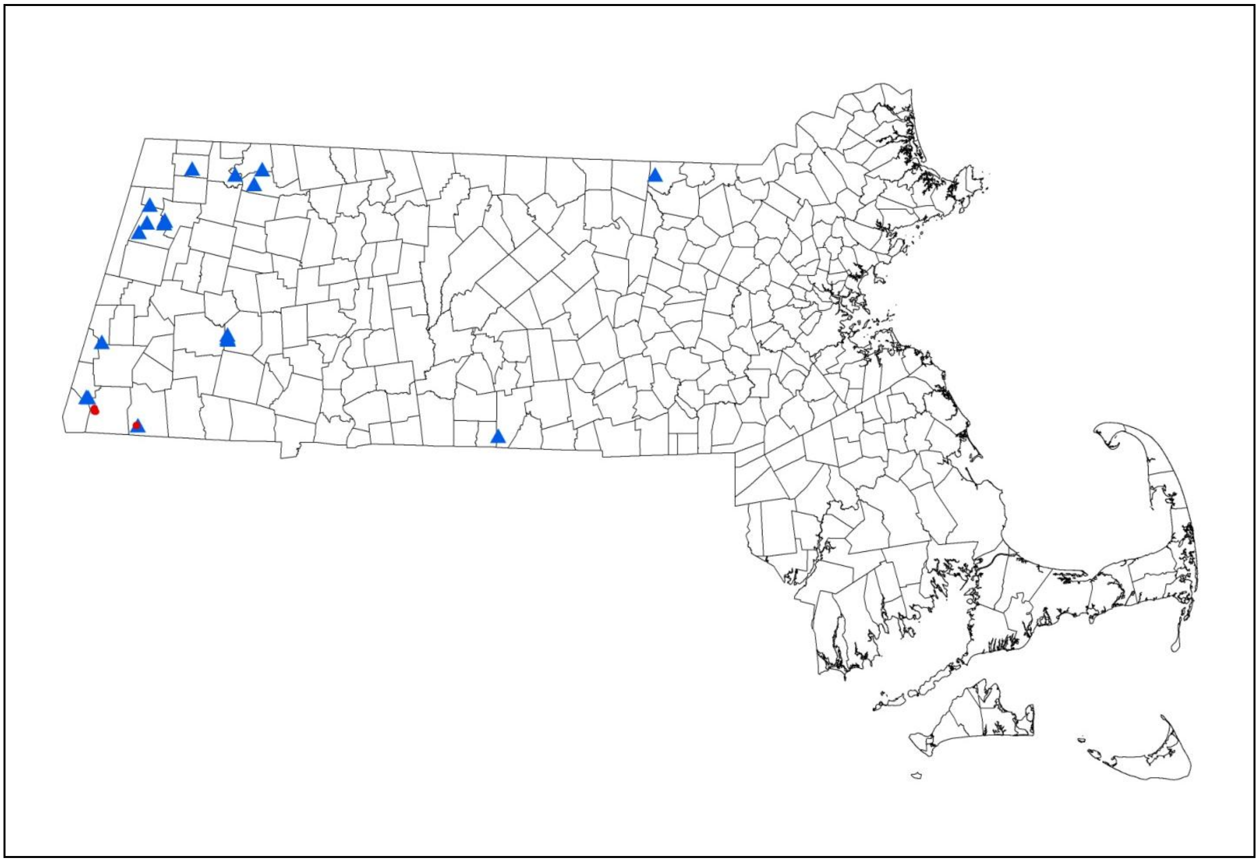


Figure 4-35: Locations of Springs, Caves, and Mines Species in Massachusetts.

Bat hibernacula are shown as blue triangles. Locations of other Springs, Caves, and Mines species are shown as red dots. Data from NHESP database.

Species of Greatest Conservation Need in Springs, Caves, and Mines

Ten SGCN are assigned to the Springs, Caves, and Mines habitat (Table 4-28).

The Sunderland Spring Planarian is restricted to a cold spring in Sunderland, Massachusetts. This spring has water temperatures of 8.5 to 9.0 degrees Celsius throughout the year. The greatest concentration of this planarian can be found living in the spring, but some animals are found just downstream of the spring on the undersides of stones and cobbles.

In Massachusetts, the Northern Spring Amphipod has only been observed at a few small calcareous springs and streams in southern Berkshire County. Elsewhere in its range, *G. pseudolimnaeus* is reported from lakes and large rivers, migrating to small streams and springs during the breeding season (Bousfield 1958). In Massachusetts, no *G. pseudolimnaeus* have been reported from lakes or rivers, though large concentrations have been observed in springs.

The stygobites include the Piedmont Groundwater Amphipod and Taconic Cave Amphipod. These are currently known from two sites and one site in Massachusetts, respectively (Smith 1997).

Eleven mines and twelve caves have been documented to harbor wintering bats in Massachusetts. Only one hibernaculum has definitely supported the Eastern Small-footed Bat within the past 25 years. The Indiana Bat has not been found in Massachusetts since 1939. The maximum documented number of bats of all species using a hibernaculum in the Commonwealth ranged up to around 7,000, but many hibernacula have considerably fewer individuals, even before the advent of White Nose Syndrome (WNS). Mines have more wintering bats than do caves: up to a maximum of 7,320 in mines, but only 110 in caves. In general, the number of bats using hibernacula in Massachusetts has increased over the past few decades (Cardoza et al., in prep). Figure 4-35 gives the approximate locations of known bat hibernacula in Massachusetts.

Bats that hibernate in Massachusetts can use any underground cavity, but most of the known large hibernacula have been in abandoned mines, as there are few caves in the state that are deep enough or long enough to have stable winter temperature regimes and thus support large numbers of wintering bats. Twelve of the 23 known hibernacula are natural caves, with a maximum number on any survey of 1,279 bats reported in 2002, before WNS invaded the state. In 2009, this same hibernaculum was resurveyed and only contained 158 bats. Similar reductions in populations have been observed in other hibernacula, along with documented evidence of WNS. With the exception of the Big Brown Bat (*Eptesicus fuscus*), all bats that hibernate in Massachusetts have been listed under the state Endangered Species Act because of the steep declines in hibernating bat numbers and the persistent threat of disease.

Known bat hibernacula in Massachusetts have been surveyed by the DFW about every ten years, starting in the 1970s, but have increased in frequency since the onset of WNS. The last series of surveys took place between 2009 and 2013. Ten of the hibernacula are on protected conservation land, and one is on land with a current conservation easement. The remaining sites are privately owned. Occasionally these sites are surveyed in the summer; however, no systematic data exist regarding summer concentrations of bats of any species.

Theconservation status of the Indiana Bat, which is federally listed as Endangered, is considered to be Historic in Massachusetts. The best-documented occurrence was in the 1930s (with a maximum of 60 individuals ever found at one site) and the species has not been found again, despite repeated searches of the original location.

Table 4-28: Species of Greatest Conservation Need in Springs, Caves, and Mines

Taxon Grouping	Scientific Name	Common Name
Misc. Invertebrates	*Polycelis remota*	Sunderland Spring Planarian
Crustaceans	*Gammarus pseudolimnaeus*	Northern Spring Amphipod
	Stygobromus borealis	Taconic Cave Amphipod
	Stygobromus tenuis tenuis	Piedmont Groundwater Amphipod
Mammals	*Eptesicus fuscus*	Big Brown Bat
	Myotis leibii	Small-footed Myotis
	Myotis lucifugus	Little Brown Myotis
	Myotis septentrionalis	Northern Myotis
	Myotis sodalis	Indiana Myotis
	Perimyotis subflavus	Tricolored Bat

Threats to Springs, Caves, and Mines

IUCN Threat 1: Residential and Commercial Development
Increased residential and commercial development may reduce localized ground water hydrology and affect hyporrheic flow of springs. Significant commercial and residential development may also reduce the suitability of caves and abandoned mines as hibernacula for bats.

IUCN Threat 2: Agriculture and Aquaculture
Agriculture and aquaculture are not major threats to springs, caves, and mines in Massachusetts.

IUCN Threat 3: Energy Production and Mining
There are limited subsurface mining operations in the Commonwealth, and abandoned mines are valuable hibernacula for bats. Localized surface mining and quarrying may affect groundwater quality in springs, and reduce habitat quality for many spring-dwelling invertebrates.

IUCN Threat 4: Transportion and Service Corridors
Transportation and service corridors are not major threats to springs, caves, and mines in Massachusetts.

IUCN Threat 5: Biological Resource Use
This is not a major threat to springs, caves, and mines in Massachusetts.

IUCN Threat 6: Human Intrusions and Disturbance
Overuse by recreational spelunkers and vandalism pose a significant threat to bat hibernacula, particularly because humans may be a vector for the spread of the White-nose fungus. However, many of the important hibernacula in the state are protected and gated. Also, the White-nose fungus is likely more quickly spread by bats than by humans. Recreational trail placement near springs may pose risk to water and habitat quality of spring-dwelling invertebrates.

IUCN Threat 7: Natural System Modifications
Poor understanding of hydrology and ecology of groundwater systems and excessive groundwater withdrawal may affect spring yield and habitat availability for spring-dwelling invertebrates.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
White-nose fungus is the greatest threat to Massachusetts bat species. Since the first detection of the disease in 2008, the most important hibernacula have exhibited significant declines, though in recent years the decline may have leveled off and populations may be stabilizing.

IUCN Threat 9: Pollution
Pollution is not a major threat to springs, caves, and mines in Massachusetts.

IUCN Threat 10: Geological Events
Natural cave-ins of caves and mines may reduce available hibernacula for bats.

IUCN Threat 11: Climate Change and Severe Weather
Changes in precipitation volume and periodicity may affect the groundwater recharge of springs. However, climate change is predicted to increase precipitation in Massachusetts, and thus may be of little consequence to the groundwater supply of natural springs.

Conservation Actions

Direct Management of Natural Resources
Continue to manage access to important bat hibernacula so as to limit detrimental impacts from human use or other factors. While many of the state-owned mines and caves may be gated, working with private landowners to gate abandoned mines may aid in reducing disturbance.

Data Collection and Analysis
Update documented sites for rare spring, cave, and mine animals, and survey nearby suitable habitat for these species.

Continue repeat survey efforts of important bat hibernacula on a regular schedule to determine the use and species composition of hibernacula across the state, and the infection intensity of WNS.

Education and Outreach
Educate state residents about the ecological benefits of bats.

Educate and inform the public about the values of spring, cave, and mine habitats and the issues related to their conservation through agency publications and other forms of public outreach, in order to instill public appreciation and understanding of these habitats.

Provide decontamination protocols and requirements for recreational caving, and work with the caving community to minimize spread of disease between sites (*National White-Nose Syndrome Decontamination Protocol 2012*).

Continue to work with the USFWS and other partners involved in reducing the spread of WNS in North America through education, research, and management.

Land and Water Rights Acquisition and Protection
Protect land around springs, caves, and mines supporting populations of rare and uncommon animals.

Law and Policy
Regulate and limit the impacts of development, gravel mining, pollutants, and water withdrawals on springs, caves, and mines used by state-listed animals.

Planning
Produce conservation and recovery plans for bats that use hibernacula in Massachusetts, and adopt methods and actions outlined in the *White-Nose Syndrome National Plan* (USFWS 2011). See http://www.whitenosesyndrome.org for more information on current and future conservation actions regarding WNS.

Develop detailed conservation and recovery plans for all SGCN associated with springs, caves, and mines. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Peatlands and Associated Habitats

Habitat Description

Peatlands are freshwater wetlands where plants grow on partially decomposed plant remains. The growing medium, peat, is usually saturated for most of the year (if not, it decomposes). Deep peat separates the plants from the underlying mineral soil and its nutrients; thus the peatland vegetation is composed of plants adapted to low-nutrient, usually acidic, wet conditions. Peatlands can be forested or open. Peatland areas often include a mosaic of forested, shrub-covered, and open peatlands.

Bogs are among the best-known peatlands and generally have the thickest peat. Bog communities receive little or no stream flow and they are isolated from the water table, making them the most acidic and nutrient-poor of peatland communities. The pH of bogs is in the range of 3 to 4. Bogs occur in a variety of physical settings, such as along pond margins, at the headwaters of streams, in kettleholes, or in isolated valley bottoms without inlet or outlet streams. They occur statewide, although most are in the north-central and western parts of the state. Most are dominated by dwarf ericaceous shrub species growing on sphagnum mosses, generally with pronounced hummock-hollow topography. Forested bogs are late-successional peatlands that typically occur on thick peat deposits. Most forested bogs are dominated by spruce or tamarack, although some, mostly in the southeastern part of the state, have an open canopy in which Atlantic White Cedar is the characteristic tree species.

Fens are shallower peatlands, where plants have more access to mineralized groundwater and therefore to more nutrients. They tend to be less acidic than bogs. Acidic fens tend to have more diversity of plant species than do bogs. Acidic graminoid fens typically have some standing water present throughout much of the growing season. Peat mats are quaking and often unstable. Calcareous fens (rich fens) in Massachusetts, found only in the western part of the state where groundwater carries calcium dissolved from surrounding limestone or marble, support a generally different flora from that occurring in acidic fens. Even in the calcium-rich areas, other nutrients are not readily available. In areas with calcareous fens, cold upwelling groundwater with few nutrients assists in maintaining peat. Calcareous fens are open, sedge-dominated wetlands occurring on slight to moderate slopes where there is calcareous groundwater seepage. They are rare-species hot spots with many associated rare plant and animal species. Calcareous fens are particularly sensitive to changes in water level and type. They are extremely uncommon habitats, and many of the rare species in them are restricted to such habitats.

Bogs and fens are often surrounded by more nutrient-rich, wetter moats with muck rather than peat, dominated by a mixture of Highbush Blueberry and Swamp Azalea. Inside the moats, the peat mat supports a mixture of tall and short shrubs that are predominantly ericaceous (members of the Heath family). Leatherleaf is dominant. Other typical ericaceous shrubs include Rhodora, Sheep Laurel, and low-growing Large and Small Cranberry. Scattered, stunted coniferous trees (primarily tamarack and Black Spruce) occur throughout, with scattered Red Maple and occasional pines. A mixture of specialized bog plants grow on the hummocky sphagnum surface, including carnivorous Pitcher Plants and sundews.

Shrub-dominated acidic peatlands are characterized by a mixture of primarily deciduous shrubs. The species and conditions overlap with shrub swamps, but tend to be less diverse. Acidic shrub fens experience some groundwater and/or surface-water flow, but not calcareous seepage. Acidic shrub fens are typically found along wet pond margins in the eastern half of the state, but they also characterize many wet pond margins in northern Worcester County.

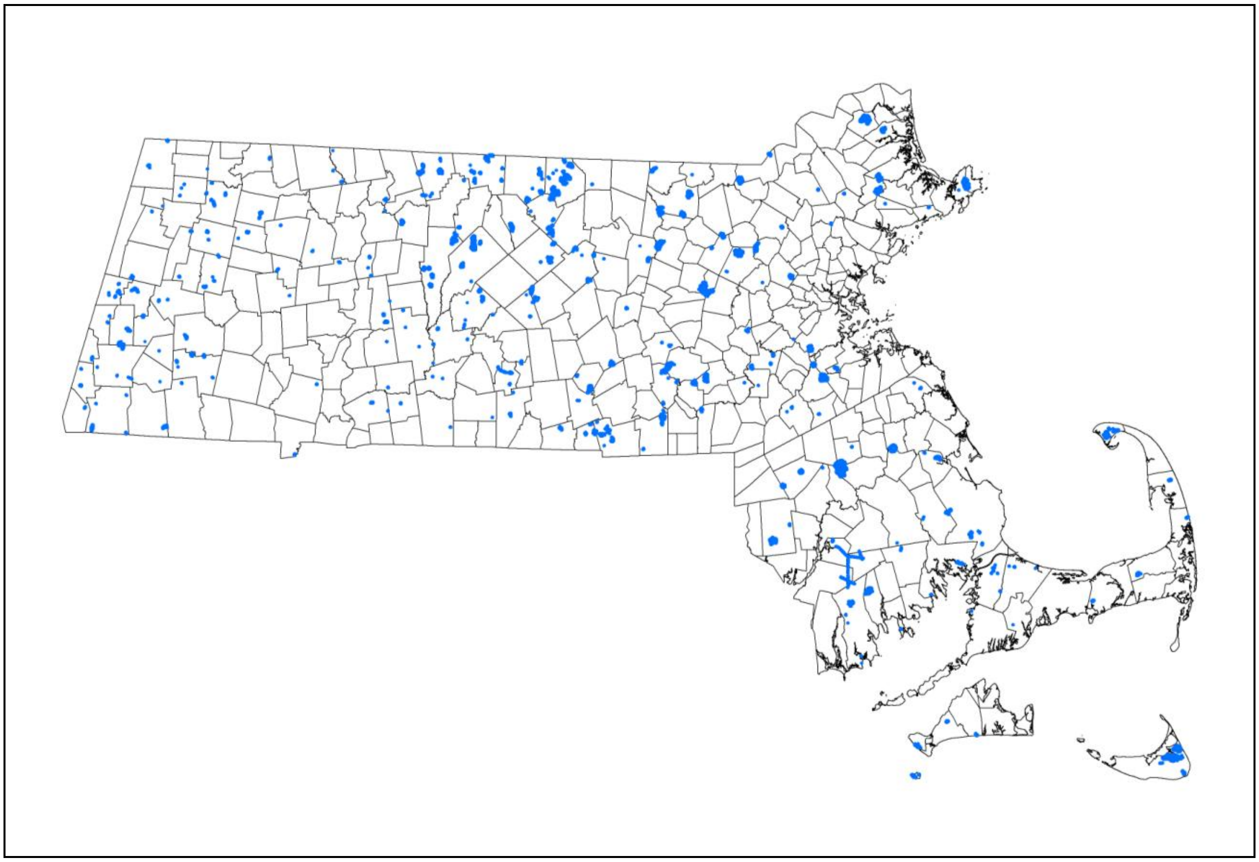


Figure 4-36: Locations of Peatlands and Peatland Species in Massachusetts.

Species of Greatest Conservation Need in Peatlands and Associated Habitats

Fifty-two SGCN are assigned to Peatlands and Associated Habitats (Table 4-29).

The high acidity and low oxygen content of the water make bogs inhospitable to many reptiles, fish, and amphibians. However, several of the state's listed rare animal species are found in bogs. Peatlands include a diversity of habitats within them. Many invertebrates specialize on the plants that are peatland specialists. Pools in the peat support several rare species of dragonflies. Moats and pools associated with all types of bogs can function as vernal pool habitat if they have two to three months of ponding and lack fish; they provide important amphibian breeding habitat.

Scattered populations of Southern Bog Lemmings are found in areas with a mix of herbaceous and shrubby vegetation, where they make runs and nests in sphagnum and among roots of shrubs. Sphagnum mats where Pitcher Plants grow provide habitat for the rare Pitcher Plant Borer Moth.

The basic habitat of Bog Turtles is open-canopy wetlands with rivulets between sedge tussocks, such as are found in open calcareous fens. Other turtles, such as Spotted Turtles, also use these habitats. Wood Turtles use these habitats if they are connected with the flowing waters of streams, brooks, tributaries, and smaller rivers associated with riparian corridors.

Large animals such as Black Bear use peatlands as part of their habitat. Blueberries and cranberries are favored foods when available. Pruning from deer browse on shrubs in and around peatlands is often obvious, as are moose and deer trails and bedding signs in sedge areas. Small birds nest in the dense shrub thickets in and around peatlands. Cover from the shrubs and trees are important parts of the habitat provided by peatlands for most animals that occur in them. Mallards, American Black Ducks, and Wood Ducks nest on peat edges when there is open water. Although increasingly rare in Massachusetts, Olive-sided Flycatchers may be found breeding in boreal spruce bogs at high elevations in western or north-central Massachusetts (Walsh and Petersen 2013). Another species of high conservation concern and a rare breeder in Massachusetts, the Rusty Blackbird has historically nested in high-elevation forested bogs in western and north-central areas in the state. Although there were no confirmed breeding records in the *Massachusetts Breeding Bird Atlas 2* (2007-2011), Rusty Blackbirds can be found using this habitat during spring and fall migration (Walsh and Petersen 2013).

Plants associated with peatlands often occur nowhere else, and are typically divided by calcareous (or alkaline) fens and bogs and acidic ones. Eastern Dwarf Mistletoe parasitizes Black Spruce in acidic kettlehole peat bogs, while Arethusa, Bog Sedge, Few-flowered Sedge, Walter's Sedge, Thread Rush and Pod-grass are other plant SGCN that occur in the acidic bogs. Swamp Birch, Glaucous Sedge, Slender Cottongrass, Labrador Bedstraw, Loesel's Twayblade, and North Wind Orchid are observed in the alkaline or calcareous fens and bogs. Pink Pyrola has been observed in calcareous coniferous fens, while Leafy White Orchid, Northern Green Orchid, Showy Lady's-slipper and Round-leaved Orchid may be found in forested calcareous fens and swamps.

Table 4-29: Species of Greatest Conservation Need in Peatlands and Associated Habitats

Taxon Grouping	Scientific Name	Common Name
Amphibians	*Lithobates pipiens*	Northern Leopard Frog
Reptiles	*Thamnophis sauritus*	Eastern Ribbonsnake
Birds	*Botaurus lentiginosus*	American Bittern
	Contopus cooperi	Olive-sided Flycatcher
	Zonotrichia albicollis	White-throated Sparrow
Mammals	*Synaptomys cooperi*	Southern Bog Lemming
Odonates	*Aeshna subarctica*	Subarctic Darner
	Somatochlora forcipata	Forcipate Emerald
	Somatochlora georgiana	Coppery Emerald
	Somatochlora incurvata	Incurvate Emerald
	Somatochlora kennedyi	Kennedy’s Emerald
	Williamsonia fletcheri	Ebony Boghaunter
	Williamsonia lintneri	Ringed Boghaunter
Lepidoptera	*Apamea inebriata*	Drunk Apamea Moth
	Callophrys hesseli	Hessel’s Hairstreak
	Callophrys lanoraieensis	Bog Elfin
	Cingilia catenaria	Chain-dotted Geometer
	Hemaris gracilis	Slender Clearwing
	Metarranthis pilosaria	Heath Metarranthis
	Papaipema appassionata	Pitcher-plant Borer
	Papaipema stenocelis	Chain-fern Borer
Plants	*Arceuthobium pusillum*	Eastern Dwarf Mistletoe
	Arethusa bulbosa	Arethusa
	Betula pumila	Swamp Birch
	Carex exilis	Bog Sedge
	Carex livida	Livid Sedge
	Carex michauxiana	Michaux's Sedge
	Carex oligosperma	Few-seeded Sedge
	Carex pauciflora	Few-flowered Sedge
	Carex striata	Walter's Sedge
	Cypripedium reginae	Showy Lady’s-slipper
	Eriophorum gracile	Slender Cottongrass
	Galium labradoricum	Labrador Bedstraw
	Gentiana linearis	Narrow-leaved Gentian
	Juncus debilis	Weak Rush
	Juncus filiformis	Thread Rush
	Linnaea borealis var. americana	American Twinflower
	Liparis loeselii	Loesel’s Twayblade
	Lycopodiella alopecuroides	Foxtail Clubmoss
	Malaxis monophyllos var. *brachypoda*	White Adder's Mouth
	Neottia bifolia	Southern Twayblade
	Neottia cordata	Heartleaf Twayblade
	Ophioglossum pusillum	Adder's Tongue Fern
	Orontium aquaticum	Golden Club
	Platanthera aquilonis	North Wind Orchid
	Platanthera dilatata	Leafy White Orchid
	Platanthera huronensis	Northern Green Orchid
	Platanthera orbiculata	Round-leaved Orchid
	Potamogeton confervoides	Tuckerman’s Pondweed
	Pyrola asarifolia ssp. *asarifolia*	Pink Pyrola
	Rhododendron maximum	Great Laurel
	Scheuchzeria palustris	Pod-grass

Threats to Peatlands and Associated Habitats

IUCN Threat 1: Residential and Commercial Development
Residential and commercial development adjacent to peatlands may impact these habitats in a variety of ways. An increase in human activity, noise, and artificial light in and adjacent to these habitats creates disturbance that may repel species from the site or interfere with their behavior. Increased human activity around these habitats may also increase the presence of mesopredators (raccoons, opossums, etc.) and domestic predators (cats and dogs). The likelihood of impact from invasive species greatly increases in the presence of development due to a high probability of new invasive species being introduced to the site, either directly (landscaping) or indirectly (introduction of contaminated soil or dumping of contaminated materials). Development often fragments these habitats by eliminating the connections to adjacent complementary upland or wetland habitats. Filling, dredging, and impoundment are direct peatland impacts associated with development, and nutrient and chemical inputs from residential and commercial development may affect water and sediment properties. Development of any kind typically alters the hydrology of the adjacent wetlands, and peatlands, particularly fens, are particularly sensitive to alteration.

IUCN Threat 2: Agriculture and Aquaculture
Agriculture around peatlands could potentially add nutrients to the ground- and surface water, encouraging growth of invasive species and leading to decomposition of the peat. Clearing land can lead to warming of the groundwater, which also leads to peat decomposition. Addition of lime to soils around acidic peatlands raises the pH of ground water and leads to peat decomposition and changes in vegetation and animal habitats.

IUCN Threat 3: Energy Production and Mining
Peat harvesting removes the substrate, changes contours and shorelines, and removes habitat for animals and plants. Although not generally an issue in Massachusetts, peat has been suggested as an energy source and was likely used in the past, particularly on the islands. Peat harvesting also changes the hydrology of the peatlands, leaving some previously saturated areas to dry and start to decompose.

IUCN Threat 4: Transportation and Service Corridors
Road and rail construction can often lead to the introduction of invasive species through contaminated soil, and construction often creates soil disturbance that is favorable for the establishment of invasives. Invasive species are also inadvertently introduced along transportation corridors by vehicles, and seeds dispersal is often further aided by moving traffic.

New construction of transportation corridors through or adjacent to peatlands may directly alter these habitats through dredging, filling, and impoundment. New construction can also alter the natural hydrology of peatlands and can fragment the habitat. Pollution introduced by road runoff has the ability to impact peatland habitats by altering water and sediment chemistry. The Massachusetts Wetlands Protection Act offers limited protection against new construction through peatlands and other wetland systems, but not complete protection. New construction would be required to try to mitigate any wetland loss through construction of new peatland wetlands—a difficult task, as these areas have formed over long periods of time.

Increased traffic along these corridors may result in direct mortality of species associated with these habitats, or result in the avoidance of the site by species due to excessive noise and artificial light.

Powerline rights-of-way change hydrology by requiring maintenance of open (not forested) corridors that change evapotranspiration of areas around and in wetlands, and change shade conditions in wetlands that are in the corridors.

Roads, adjacent to and through peatlands and related habitats, discharge stormwater with road salt and its associated chemicals, particularly chloride, into these wetlands. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into associated wetland systems, and threatening these ecosystems with this chemical, which is toxic to plants and animals at high concentrations.

IUCN Threat 5: Biological Resource Use
Mining peat is a clear threat, although uncommon in Massachusetts. This activity particularly threatens Foxtail Clubmoss.

IUCN Threat 6: Human Intrusions and Disturbance
All peat is susceptible to decomposition from trampling. Heavily visited sites need un-intrusive boardwalks. Showy Lady's-slipper, Arethusa, and the other showy orchids are threatened with collection from people who do not realize the damage they do by collection.

IUCN Threat 7: Natural System Modifications
Peatlands are maintained by the presence of cold, low-nutrient water. Altering the amount of water, adding nutrients, or increasing its temperature all threaten peatlands. The presence of peat makes bogs and fens different from other wetlands and provides the distinct habitat that specialist species need.

Increased development, additional areas of pavement, and other non-porous surfaces, have led to an increase in shallow groundwater temperatures (Eggleston and McCoy 2015). As peatlands are so dependent on cool groundwater inputs, warmer water entering these habitats may have a deleterious effect on their associated plant and animal SGCN.

Natural succession from open to shrubby to closed canopy habitats is a threat to many of the plant SGCN, including several of the orchids.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Common Reed (*Phragmites australis)* is an aggressive nonnative species that is a serious threat to peatland habitat throughout the state. Nonnative Common Reed may greatly reduce the biodiversity of peatland habitats by inhibiting native vegetation, displacing native food plants, and creating an undesirable structure for peatland animal species. Other invasive species, such as Glossy Buckthorn (*Frangula alnus*), as well as native trees such as Red Maple (*Acer rubrum*) may invade these habitats, shade out, and compete with rare plant species.

Beavers can be a problem through the alteration of water levels. The plant species adapted to these habitats are very sensitive to hydrologic changes.

Developing strategies to prevent or reduce browsing by geese on Golden Club is important to the species' long-term survival in Massachusetts.

IUCN Threat 9: Pollution
Peatlands and associated habitats are vulnerable to nutrient loading and/or chemical contamination when they are adjacent to lawns, golf courses, crop fields, parking lots, roads, gas stations, and other areas where accidental spills or deliberate applications of chemicals occur. Surface runoff from those areas can introduce contaminants to wetlands, thus altering their soil and water chemistry and impairing biological function. Peatlands are typically afforded 100-foot terrestrial buffers (via the Massachusetts Wetlands Protection Act) to help mitigate the threat of contamination by runoff, but those regulatory protections do not apply to land uses that were in place prior to enactment of the legislation. Given the high human population density in Massachusetts, many peatlands are vulnerable to chemical contamination via surface runoff.

IUCN Threat 10: Geological Events
These are not a significant threat to these habitats.

IUCN Threat 11: Climate Change and Severe Weather
Climate change with increasing warmth would lead to decomposition of peat. Changes in precipitation would affect the wetlands with more or less water. All of the plant SGCN are susceptible to changes in hydrology. Some of the plant SGCN are at the southern edge of their range in Massachusetts, including Heartleaf Twayblade, and therefore are likely to be particularly susceptible to changes associated with warming trends.

Conservation Actions

Direct Management of Natural Resources
Addressing invasive species in peatland habitats is a priority conservation action. Protocols to prevent the establishment of invasive species, either through controlling potential vectors (contaminated soil, landscaping, etc.), or addressing pioneering invasive populations through early-detection-rapid-response programs are important ways of dealing with invasive species before they are impacting a habitat. Programs to proactively treat established invasive species are key to restoring important peatland habitats and should be pursued whenever possible.

Introducing appropriate disturbance regimes (fire, mowing, grazing, etc.) is important to maintain the structure and species composition of some peatland habitats. Applying a disturbance regime to peatland habitat should only be undertaken if there is a demonstrated need for this management.

Install protective fencing as needed to protect plant SGCN (such as Showy Orchids) from deer browsing. Monitor the success of such protective fencing and adapt management as needed.

Data Collection and Analysis
Complete the field surveying and ranking of peatlands, to supplement the reports of 1994 and 1999.

Incorporate large peatlands in any future marshbird surveys, as American Bitterns can often be found associated with large peatland habitats.

Work with the Rusty Blackbird Working Group to survey for Rusty Blackbirds during migration (e.g., Rusty Blackbird Migration Blitz; http://rustyblackbird.org/outreach/migration-blitz/).

Core peatlands with a suspected fire history to determine the appropriateness of introducing a prescribed fire regime to those peatlands.

Initiate studies to determine the effect of road salt on peatland chemistry, especially at roadside peatlands known to support SGCN.

Research the natural history of peatland animals and plants.

Education and Outreach
Educate and inform the public about the values of peatland habitats and the issues related to their conservation through agency publications and other forms of public outreach, to instill public appreciation and understanding of these resources.

Conservation commissions and the DEP, through the administration of the Wetlands Protection Act, play a critical role in determining the feasibility of peatland restoration. Establishing a program to ease the permitting burden on land managers with approved restoration plans would greatly facilitate needed peatland restoration projects.

Harvest and Trade Management
This potential conservation action is not warranted for this habitat.

Land and Water Rights Acquisition and Protection
Protecting from development land in and around peatlands that support populations of rare and uncommon animals is important to buffer these resources from disturbance and to allow management and restoration when needed.

Law Enforcement
Regulate and limit the impacts of development, nutrient additions, and water withdrawals on peatlands used by state-listed animals and plants.

Law and Policy
This potential conservation action is not warranted for this habitat.

Planning
Develop detailed conservation and recovery plans for SGCN associated with peatlands. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Species Reintroduction and Stocking
Conduct species introduction/reintroduction/ augmentation projects with peatlands as release sites. Translocation of SGCN to new sites or to sites of

historical occurrence is a developing conservation strategy in Massachusetts. The approach could prove to be an effective way to reestablish local populations where only the organisms have been lost, but the habitat remains, as might occur with episodic disease outbreaks. In areas where appropriate management can be assured, as on state-owned Wildlife Management Areas, introduction and reintroduction of listed plant species may be appropriate.

Marshes and Wet Meadows

Habitat Description

Marshes and wet meadows are some of the most important inland habitats for numerous species of animals, both rare and common. As defined here, this habitat type includes deep and shallow emergent marshes, wet meadows, kettlehole wet meadows, coastal interdunal marshes/swales, calcareous sloping fens, calcareous seepage marshes, calcareous basin fens, and acidic graminoid fens. These natural community types are described briefly below; see Swain and Kearsley (2015) for more detail on each of these.

Sections of most of these natural communities – the edges of emergent marshes adjacent to uplands, for example – can be free of fish and may function as vernal pools, attracting breeding Wood Frogs and Spotted Salamanders, as well as other animals that breed, feed, or rehydrate in vernal pools.

Deep Emergent Marsh

Deep Emergent Marshes generally form in broad, flat areas bordering low-energy rivers and streams or along pond and lake margins. The soils are a mixture of organic and mineral components. There is typically a layer of well-decomposed organic muck at the surface overlying mineral soil. There is standing or running water during the growing season and throughout much of the year. Water depth averages between 6 inches and 3 feet. Deep Emergent Marshes are often associated with Shrub Swamps, and the two communities intergrade.

Shallow Emergent Marsh

Shallow Emergent Marshes occur in settings similar to those of Deep Emergent Marshes, i.e., in broad, flat areas bordering low-energy rivers and streams, often in backwater sloughs, or along pond and lake margins. Unlike Deep Emergent Marshes, Shallow Marshes commonly occur in abandoned beaver flowages, and in some states this type of natural community is named “abandoned beaver meadows” or “beaver flowage communities.” The soils are a mixture of organic and mineral components. There is typically a layer of well-decomposed organic muck at the surface overlying mineral soil. There is standing or running water during the growing season and throughout much of the year, but water depth is less than in Deep Emergent Marshes and averages less than 6 inches.

Wet Meadow

Wet Meadows occur in lake basins, wet depressions, along streams, and in sloughs and other backwater areas with impeded drainage along rivers. The mucky mineral soils are permanently saturated and flood occasionally, but standing water is not present throughout the growing season, as in Deep and Shallow Emergent Marshes. As these communities flood only temporarily, continued disturbance is necessary to prevent encroachment by woody plants.

Kettlehole Wet Meadow

Kettlehole Wet Meadows are a variant of wet meadows that are restricted to glacial kettleholes in sandy outwash soils that have seasonal water-level fluctuations. They are seasonally inundated by local runoff and groundwater fluctuations, and they typically have no inlet or outlet. For most of the summer, they look like shallow ponds, but by late summer they are covered by emergent vegetation. Soils are typically shallow, mucky peats. Deep peat does not develop due to the seasonal drawdown of water. The hydrology of Kettlehole Wet Meadows is similar to coastal plain ponds. Both are characterized by a series of plant associations occurring along a gradient from the higher, drier margins to the lower, wetter centers. Kettlehole Wet Meadows can function as vernal pool habitat if water remains standing for 2-3 months; these areas provide important amphibian breeding habitat.

Coastal Interdunal Marsh/Swale

Interdunal swales are low, shallow depressions that form between sand dunes along the coast. They occur as part of a dune system, and the best examples are complexes of numerous swales. Soils generally have a thin organic layer (about 1 cm) over coarse sand. The water regime ranges from seasonally flooded to permanently inundated.

Calcareous Seepage Marsh

This natural community is a mixed herbaceous/graminoid/shrub wetland, which experiences some calcareous groundwater seepage. Calcareous Seepage Marshes are intermediate in richness of the three calcareous fen communities described in Massachusetts. This community type is found in a variety of physical settings: in basins, in canopy gaps in rich forested swamps, in current or former beaver drainages, or in level to slightly sloping sites associated with sloping fens. There are typically 50-200+ cm of moderately to well-decomposed organic sediments.

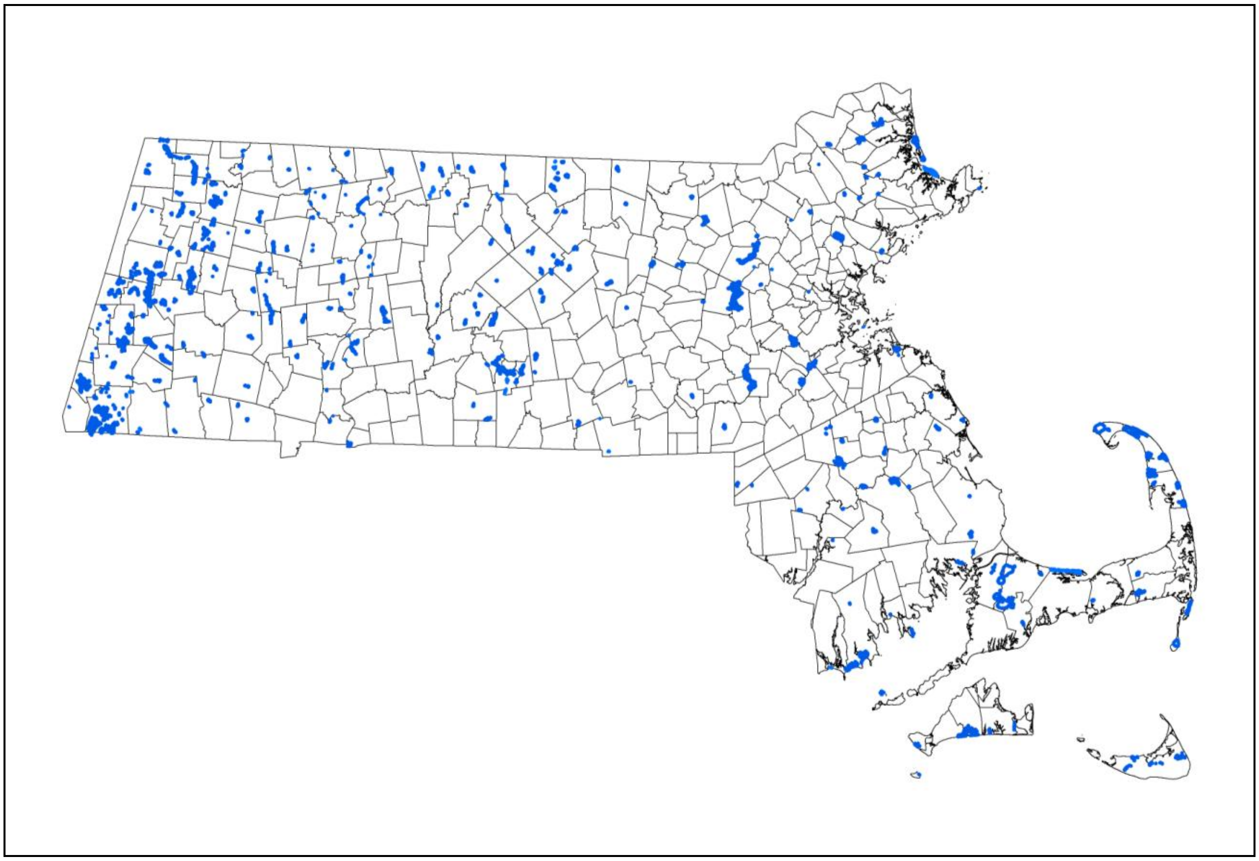


Figure 4-37: Locations of Selected Marshes and Wet Meadows in Massachusetts.

Species of Greatest Conservation Need in Marshes and Wet Meadows

Sixty-eight SGCN are assigned to the Marshes and Wet Meadows habitat (Table 4-30).

Marshes, in particular Deep Emergent Marshes and Shallow Emergent Marshes dominated by *Typha*, are the primary habitats supporting the suite of secretive marsh birds (Sora, King Rail, Least Bittern, American Bittern, and Pied-billed Grebe), American Black Duck, and Marsh Wren. Large patches of Wet Meadow are the key habitat for such species as Wilson's snipe and Sedge Wren. Large patches of marshes and meadows of various types are important breeding habitats for American Bittern and Northern Harrier.

A number of other species of conservation concern are found in marshes and wet meadows, including: Blue-spotted Salamander, Eastern Spadefoot, Spotted Turtle, Wood Turtle, Blanding's Turtle, Upland Sandpiper, Southern Bog Lemming, Northern Spring Amphipod, Taconic Cave Amphipod, Agassiz's Clam Shrimp, American Clam Shrimp, Pitcher Plant Borer Moth, Chain Fern Borer Moth, Ebony Boghaunter, and Ringed Boghaunter. These species are more commonly associated with other habitats, such as vernal pools and grasslands, and are covered under those habitat sections.

Many other more common animals use marshes and wet meadows for feeding, nesting, roosting, cover, and movement corridors. There are too many such species to list, but some obvious examples are Pickerel Frog, Common Gartersnake, Great Blue Heron, Red-winged Blackbird, White-tailed Deer, Muskrat, crayfish, and many dragonflies and damselflies.

Marshes and wet meadow are habitat for 46 state-listed and SGCN plant species. Several of these species are found in areas where calcium-rich groundwater discharge seeps are present, including Swamp Birch, Chestnut-colored Sedge, Creeping Sedge, Handsome Sedge, Dioecious Sedge, Fen Sedge, Hemlock Parsley, Showy Lady's-slipper, Few-flowered Spike-sedge, Northern and Labrador Bedstraw, Capillary Beak-sedge, Hooded Ladies'-tresses, Sessile Water-speedwell, and Culver's-root. Although Swamp Birch is a shrub, its preferred habitat is open, calcium-rich wet meadows. Some plants are associated with open habitats in floodplains, such as Foxtail Sedge, Hairy-fruited Sedge, Tussock Hairgrass, Andrews' Bottle Gentian, Winged Monkey-flower, Muskflower, Swamp Lousewort and Britton's Violet. Finally, some are associated with Acidic Graminoid Fens: Bailey's Sedge, Michaux's Sedge, Narrow-leaved Gentian, Thread Rush, Loesel's Twayblade, Green Adder's Mouth, Adder's Tongue Fern, Pale Green Orchid, Northeastern Bulrush, Long's Bulrush, and Swamp Wedgescale.

Table 4-30: Species of Greatest Conservation Need in Marshes and Wet Meadows

Taxon Grouping	**Scientific Name**	**Common Name**
Amphibians	*Lithobates pipiens*	Northern Leopard Frog
Reptiles	*Thamnophis sauritus*	Eastern Ribbonsnake
	Opheodrys vernalis	Smooth Greensnake
	Glyptemys muhlenbergii	Bog Turtle
Birds	*Anas discors*	Blue-winged Teal
	Anas rubripes	American Black Duck
	Porzana carolina	Sora
	Cistothorus palustris	Marsh Wren
	Gallinago delicata	Wilson's Snipe
	Podilymbus podiceps	Pied-Billed Grebe
	Botaurus lentiginosus	American Bittern
	Ixobrychus exilis	Least Bittern
	Circus cyaneus	Northern Harrier
	Rallus elegans	King Rail
	Gallinula galeata	Common Gallinule
	Cistothorus platensis	Sedge Wren
Lepidoptera	*Apamea inebriata*	Drunk Apamea Moth
	Euphyes dion	Dion Skipper
	Neoligia semicana	Northern Brocade Moth
	Pieris oleracea	Mustard White
	Photedes inops	Cord-grass Borer
Plants	*Betula pumila*	Swamp Birch
	Botrychium simplex	Least Moonwort
	Cardamine dentata	Fen Cuckoo Flower
	Carex alopecoidea	Foxtail Sedge
	Carex baileyi	Bailey's Sedge
	Carex castanea	Chestnut-colored Sedge
	Carex chordorrhiza	Creeping Sedge
	Carex formosa	Handsome Sedge
	Carex gracilescens	Slender Woodland Sedge
	Carex michauxiana	Michaux's Sedge
	Carex schweinitzii	Schweinitz's Sedge
	Carex sterilis	Dioecious Sedge
	Carex tetanica	Fen Sedge
	Carex trichocarpa	Hairy-fruited Sedge
	Conioselinum chinense	Hemlock-parsley
	Cypripedium reginae	Showy Lady's-slipper
	Deschampsia cespitosa ssp. *glauca*	Tussock Hairgrass
	Eleocharis quinqueflora	Few-flowered Spike-sedge
	Galium boreale	Northern Bedstraw
	Galium labradoricum	Labrador Bedstraw
	Gentiana andrewsii	Andrews' Bottle Gentian
	Gentiana linearis	Narrow-leaved Gentian
	Juncus filiformis	Thread Rush
	Lathyrus palustris	Marsh-pea
	Liparis loeselii	Loesel's Twayblade
	Lobelia siphilitica	Great Blue Lobelia
	Malaxis unifolia	Green Adder's Mouth
	Mimulus alatus	Winged Monkey-flower
	Mimulus moschatus	Muskflower
	Ophioglossum pusillum	Adder's Tongue Fern
	Pedicularis lanceolata	Swamp Lousewort
	Platanthera aquilonis	North Wind Orchid

Taxon Grouping	Scientific Name	Common Name
	Platanthera cristata	Crested Fringed Orchid
	Platanthera dilatata	Leafy White Orchid
	Platanthera flava var. *herbiola*	Pale Green Orchid
	Platanthera huronensis	Northern Green Orchid
	Platanthera orbiculata	Round-leaved Orchid
	Rhynchospora capillacea	Capillary Beak-sedge
	Scirpus ancistrochaetus	Northeastern Bulrush
	Scirpus longii	Long's Bulrush
	Sisyrinchium mucronatum	Slender Blue-eyed Grass
	Sphenopholis pensylvanica	Swamp WEdgescale
	Spiranthes romanzoffiana	Hooded Ladies'-tresses
	Symphyotrichum praealtum	Willow Aster
	Veronica catenata	Sessile Water-speedwell
	Veronicastrum virginicum	Culver's-root
	Viola brittoniana	Britton's Violet

Threats to Marshes and Wet Meadows

IUCN Threat 1: Residential and Commercial Development

Residential and commercial development adjacent to marshes and wet meadows may impact these habitats in a variety of ways. An increase in human activity, noise, and artificial light in and adjacent to these habitats creates disturbances that may repel species from the site or interfere with their behavior. Increased human activity around these habitats may also increase the presence of mesopredators (raccoons, opossums, etc.) and domestic predators (cats and dogs). The likelihood of impact from invasive species greatly increases in the presence of development, due to a high probability of new invasive species being introduced to the site, either directly (landscaping) or indirectly (introduction of contaminated soil or dumping of contaminated materials). Development often fragments these habitats by eliminating the connection to adjacent complementary upland habitats or by blocking aquatic connections to other wetlands. Filling, dredging, and impoundment are direct wetland impacts associated with development, and nutrient and chemical inputs from residential and commercial development may affect water and sediment properties. The influence of development may result in the alteration or elimination of important natural processes, such as cyclical beaver activity or seasonal flooding.

Several of the plant SGCN of this habitat, such as Culver's-root, Capillary Beak-Sedge, Green Adder's Mouth, Fen Cuckoo Flower, and Round-leaved Orchid, appear to be particularly sensitive to nearby development of any kind, as they sometimes disappear from what seem to be unimpacted wetlands when development occur on adjacent uplands.

IUCN Threat 2: Agriculture and Aquaculture

Agricultural runoff (fertilizers, pesticides) has the ability to impact marsh and wet-meadow habitats by altering water and sediment chemistry. Where chemical inputs are high, amphibians may incur reduced survivorship from toxicological and behavioral effects. Dioecious Sedge, Hemlock Parsley, Thread Rush, Winged Monkey-flower, Hooded Ladies'-tresses and Culver's-root are all quite sensitive to fertilizers and pesticides. Sedimentation from agricultural runoff can also negatively impact many of these marsh and wet meadow species.

IUCN Threat 3: Energy Production and Mining

This is not a significant threat to these habitats.

IUCN Threat 4: Transportation and Service Corridors

Road and rail construction can often lead to the introduction of invasive species through contaminated soil, and construction often creates soil disturbance that is favorable for the establishment of invasives. Invasive species are also inadvertently introduced along transportation corridors by vehicles, and seeds dispersal is often further aided by moving traffic.

New construction of transportation corridors through marshes and wet meadows may directly alter these habitats through dredging, filling, and impoundment. New construction can also alter the natural hydrology of marshes and wet meadows and can fragment the habitats. Pollution introduced by road runoff has the ability to impact marsh and wet-meadow habitats by altering water and sediment chemistry.

Increased traffic along these corridors may result in direct mortality and/or barriers to movement for species associated with these habitats, or result in the avoidance of the site by species due to excessive noise and artificial light.

Roads near and through these areas also bring an increase in road salt and its associated components, chloride in particular. Between 1990 and 2011, average concentrations of chloride in northern U.S. streams have doubled, exceeding the rate of urbanization (Corsi et al. 2015). The findings in this paper indicate that the chloride levels in the groundwater are slowly increasing over time, feeding water with higher chloride levels into adjacent wetland systems, and threatening these ecosystems with this chemical, which is toxic at high concentrations.

IUCN Threat 5: Biological Resource Use
Some SGCN (e.g., Bog Turtle, Blanding's Turtle, Spotted Turtle) that depend on marshes and wet meadows are poached for the pet trade or other illegal uses. The magnitude of the problem in Massachusetts is unknown, but poaching is of great concern regarding globally rare SGCN (e.g., Bog Turtle).

IUCN Threat 6: Human Intrusions and Disturbance
Off-road vehicles (ORVs) can cause significant damage to these habitats and species in a short period of time, and in areas with SGCN, ORVs should have very limited or no access.

Mowing of wet meadows for agricultural, scenic, or habitat management purposes can have a deleterious effect on SGCN in this habitat. For example, Hairy-fruited Sedge should have minimal mowing during early spring or late fall and none during the summer so that it can effectively compete with other species in its habitat.

IUCN Threat 7: Natural System Modifications
Beaver activity threatens calcareous fen communities by flooding the habitat and altering surface-water chemistry. There is evidence to suggest that ponding of water by beaver dams may increase the water's relative acidity, possibly due to the accumulation of organic acids or to dilution from acid rain. Several of the plant SGCN (Swamp Lousewort in particular) have been negatively impacted by beaver flooding.

For Kettlehole Wet Meadows in particular, it is known that seasonal wate- level fluctuations play an important role. Spring high-water levels prevent encroachment of woody shrubs and trees, and late-summer low-water levels allow the characteristic narrow-leaved emergent plants to appear. Any alteration in natural water-level fluctuations, such as groundwater withdrawal, will negatively affect the community.

Some marshes and wet meadows, and especially open calcareous fens, are fire-adapted communities that require regular fire events (often on a broad return frequency) to maintain their structure and species composition. In the absence of fire, introducing an alternative disturbance regime to these systems, such as grazing or mowing, may be necessary to maintain open fen habitats. The exclusion of fire particularly threatens Long's Bulrush, which is usually only observed flowering after fire. Capillary Beak-sedge may also need fire or an alternative disturbance to its habitat.

Flood-control projects and other anthropogenic manipulations of water levels in marsh habitats may disrupt normal hydrological conditions and/or cycles to which local flora and fauna are adapted. Such projects are presumed to have reduced aquatic habitat available to Northern Leopard Frogs, and management of at least one site in Massachusetts must take needs of Blanding's Turtles into consideration.

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Common Reed (*Phragmites australis*), Reed Canary Grass (*Phalaris arundinacea*), and Purple Loosestrife (*Lythrum salicaria*) are three aggressive nonnative species that can be abundant in marshes and wet meadows throughout the state. These three invasive exotics may greatly reduce the biodiversity of these habitats by inhibiting native vegetation, displacing native food plants, and creating an undesirable structure for marsh and wet meadow animal species. Invasive plant species may shade plant SGCN, leading to smaller populations.

Emerging infectious disease is currently considered one of the greatest threats to global biodiversity, with amphibians and reptiles considered especially vulnerable groups. Although amphibians in the New England region appear to be relatively resistant to some pathogens that are problematic elsewhere in the world (e.g., the chytrid fungus *Batrachochytrium dendrobatidis* [*Bd*]), other pathogens (e.g., ranavirus) are considered significant threats to multiple taxa in the region. The introduction and spread of pathogens among marshes and other wetlands may be facilitated by animal commerce, illegal animal translocations, use of contaminated field gear during biological surveys, and natural dispersal of native fauna. Infection rates and long-term impacts to organisms associated with marshes and wet meadows are understudied in Massachusetts. However, ranavirus is known to affect or be carried by a wide variety of taxa (e.g., frogs, salamanders, turtles, fish), sometimes causing severe symptoms in individuals and mass mortalities in local areas. Several recent mortality events in Massachusetts and Maine are suspected to be the result of ranavirus outbreaks.

IUCN Threat 9: Pollution
Marshes are vulnerable to nutrient loading and/or chemical contamination when they are adjacent to lawns, golf courses, crop fields, parking lots, roads, gas stations, and other areas where accidental spills or deliberate applications of chemicals occur. Surface runoff from those areas can introduce contaminants to wetlands, thus altering their soil and water chemistry and impairing biological function. Marshes and wet meadows are typically afforded 100-foot terrestrial buffers (via the Massachusetts Wetlands Protection Act) to help mitigate the threat of contamination by runoff, but those regulatory protections do not apply to land uses that were in place prior to enactment of the legislation. Given the high human-population density in Massachusetts, many marshes are vulnerable to chemical contamination via surface runoff.

Acidification of marshes and other wetlands (e.g., from acid precipitation) may alter plant communities and threaten productivity of some amphibian species that appear intolerant of acidic waters (e.g., Northern Leopard Frog).

IUCN Threat 10: Geological Events
These are not a significant threat to these habitats.

IUCN Threat 11: Climate Change and Severe Weather
Climate change analyses project varying scenarios for the northeastern U.S. Although total precipitation is expected to increase, other common predictions include warmer temperatures, longer and more severe summer droughts, shorter but more intense winter/spring floods, and reduced extent and duration of winter snow cover. Taken together, such changes could alter the hydrological regimes of many marshes and wet meadows in the region. Expected outcomes include seasonal drying of wetland soils, which could facilitate changes in dominant vegetation. Smaller marshes and wet meadows could be lost entirely, while larger ones could contract in area or become fragmented. Hence, climate change poses significant threats to local populations of SGCN by potentially reducing the availability of marsh and wet meadow habitats.

Recent research indicates that the last two decades have been the wettest years in the Northeast in 500 years (Pederson et al. 2014, 2013, Newby et al. 2014, Weider and Boutt 2010). Such increases could also lead to flooding of natural wetland systems.

The cumulative impacts of increasing nonporous surfaces and climate change have been implicated in rising temperatures in an aquifer (Eggleston and McCoy 2015). Rising groundwater temperatures would have several implications for marsh and wet-meadow ecology, including flow rates and metabolism changes.

Conservation Actions

Direct Management of Natural Resources
Addressing invasive species in marsh and wet meadow habitats is a priority conservation action. Protocols to prevent the establishment of invasive species, either through controlling potential vectors (contaminated soil, landscaping, etc.), or addressing pioneering invasive populations through early-detection-rapid-response programs are important ways of dealing with invasive species before they are impacting a habitat. Programs to proactively treat established invasive species are key to restoring important marsh and wet

meadow habitats and should be pursued whenever possible.

Introducing appropriate disturbance regimes (fire, mowing, grazing, etc.) is important to maintain the structure and species composition of some marsh and wet-meadow habitats. Applying a disturbance regime to marsh and wet-meadow habitat should only be undertaken if there is a demonstrated need for this management.

Some critically important marshbird habitat in Massachusetts is a direct result of water-level manipulation, especially at impoundments on wildlife refuges. Impoundments that support significant populations of marshbirds should be managed in a way that is conducive to perpetuating these populations.

Data Collection and Analysis

Marshbird populations are dynamic and a survey of the state's habits is needed to evaluate status and conservation needs. Systematic call-and-response surveys targeting representative habitat across the state should be undertaken to determine species' current populations and distributions, as well as to identify important management needs.

Coring marshes and wet meadows, especially calcareous fens with a suspected fire history, to learn about fire history is an important undertaking to determine the appropriateness of introducing a prescribed fire regime to important wetlands.

Initiating studies to understand the role that *Typha* played in open wetlands such as calcareous fens would inform future management where *Typha* appears to be becoming dominant in these habitats.

Initiating studies to understand potential nonnative *Typha* species and *Typha* hybrids in Massachusetts to understand what their impact on the state's wetlands is important.

Initiating studies to determine the effects of road salt on wetland chemistry, especially at calcareous marshes, is important.

Long-term monitoring of Blanding's, Spotted, Wood, and Bog turtle populations, using standardized regional protocols, where available, is a high priority.

Conduct biological surveys of marshes and wet meadows for SGCN. Biological inventory and monitoring of marshes and wet meadows are necessary to identify and understand the distribution and abundance of associated SGCN. Data generated by such surveys are critical to establishing and maintaining site-specific regulatory protections for SGCN and to developing effective, long-term conservation plans for the species. Biological inventory data are needed to assess the basic population statuses of some SGCN, answer outstanding questions about population genetics, or even confirm suspected species identities (e.g., certain local populations of leopard frogs).

Education and Outreach

Conservation commissions and the DEP, through the administration of the Wetlands Protection Act, play a critical role in determining the feasibility of wetland restoration. Establishing a program to ease the permitting burden on land managers with approved restoration plans would greatly facilitate needed wetland-restoration projects.

Educate conservation commissions regarding the importance of marshes and wet meadows. Forested wetlands receive relatively much more attention in guidance documents from the DEP, yet both are important.

Educate the public and key decision makers about the importance of actively managing priority wetland sites to maintain habitat and biological diversity.

Produce and provide educational products, services, and opportunities to the Massachusetts public regarding marsh and wet-meadow ecology and conservation. Keeping the public knowledgeable about marsh and wet-meadow ecology and the importance of those wetland systems to SGCN is prerequisite to raising awareness of conservation needs. Providing educational services and opportunities for hands-on experience are key ways to keep the public interested and active in wetland conservation. Together, those actions should help foster public support for wetlands research, regulatory protections, and conservation initiatives. Products, services, and opportunities may include marsh and wet meadow publications, website development, technical support for school studies/programs, coordination of citizen-science projects, public presentations, and the inclusion of individuals in the NHESP's biological survey and/or restoration work.

Harvest and Trade Management
This potential conservation action is not warranted for this habitat.

Land and Water Rights Acquisition and Protection
Protecting from development land in and around marshes and wet meadows that support populations of rare and uncommon plants and animals is important to buffer these resources from disturbance and to allow management and restoration when needed.

Law Enforcement
Regulate and limit the impacts of development, nutrient inputs, and water withdrawals on marshes and wet meadows used by state-listed animals.

Continue to implement legal mandates of the Massachusetts Endangered Species Act (M.G.L. c. 131A) and regulations (321 CMR 10.00).

Enforce other laws that protect SGCN associated with marshes and wet meadows. Hunting regulations (321 CMR 3.05) prohibit disturbance, harassment, or other taking of SGCN associated with marshes and wet meadows, such as Blue-spotted Salamander, Eastern Spadefoot, Northern Leopard Frog, Bog Turtle, Blanding's Turtle, and Spotted Turtle.

Law and Policy
Develop or update regulations and policies as necessary to address emerging threats. Needs to adopt new regulations and/or policies may arise as knowledge is gained about climate change, emerging infectious disease, animal or plant trade, and other threats.

Planning
Develop and maintain lists of marshes and wet meadows that should be considered priorities in future biological surveys for SGCN. Discovery of undocumented local populations of SGCN is a conservation priority. Additional priorities include identification of all discrete wetlands currently used by a given local population of SGCN (e.g., in a metapopulation of American Bittern) and an evaluation of the relative importance of each wetland to the population. Biological survey continues to be a cornerstone of the conservation strategy for marsh/wet meadow SGCN, as the data generated are invaluable to informing other types of conservation actions. Identification and prioritization of prospective survey sites is an essential planning activity to maximize survey efficacy.

Develop detailed conservation and recovery plans for SGCN associated with marshes and wet meadows. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Develop strategies for stabilizing "Priority Habitat" maps as they pertain to marsh/wet meadow SGCN. As one conservation strategy for species listed as Endangered, Threatened, or Special Concern pursuant to the MESA, the NHESP delineates Priority Habitat as a screening tool to regulate certain projects involving habitat alterations. Priority Habitat maps are updated periodically to reflect new information about the occurrences of state-listed rare species, but the magnitude of changes in the maps from one cycle to the next can create a number of challenges that reduce the efficacy of the strategy. This problem is applicable to several marsh/wet meadow SGCN, and there is a need to develop strategies for increasing the long-term stability of delineated habitat footprints. At minimum, the process will need to account for long-range population objectives and biological inventory demands, and it will need to complement other conservation strategies effectively.

Species Reintroduction and Stocking
Conduct species introduction/reintroduction/ augmentation projects with marshes/wet meadows as release sites. Translocation of SGCN to new sites or to sites of historical occurrence is a developing conservation strategy in Massachusetts; current projects involve Blanding's Turtle and Eastern Spadefoot. Likewise, augmentation of existing populations through captive rearing or head-starting of individuals for later release into those populations is an established, ongoing activity (e.g., Blanding's Turtle, Red-bellied Cooter). Reintroduction and stocking may grow as a conservation tool and involve additional SGCN, including some associated with marshes and wet meadows. The approach could prove to be an effective way to reestablish local populations where only the organisms have been lost, but the habitat remains, as might occur with episodic disease outbreaks.

Rocky Coastlines

Habitat Description

Animal species of conservation concern in this habitat are primarily using the sea along these coastlines for feeding and resting; occasionally they will roost or haul themselves out on the rocks for short periods.

In Massachusetts, only small areas of the coastline are significantly rocky (see Figure 4-38). Along the mainland coast, Cape Ann, consisting of the towns of Rockport, Gloucester, and Manchester-by-the-Sea, has rock cliffs along most of its coast. Southward along the coast, there are occasional rocky points here and there, many of which are heavily built up with homes. Cape Cod has a few areas of scattered rocks, but as the peninsula is mostly moraines left from glacial retreats, very little of the Cape has much bedrock at the surface. However, the southern shore of the lower Cape, along Buzzards Bay, is largely rocky, but not with the bedrock cliffs characteristic of Cape Ann. Rather, here the rocks are the remnants of a terminal moraine. On the Islands, only Martha's Vineyard has a rocky coastline, along its western edge. The Elizabeth Islands, separating Buzzards Bay and the Vineyard Sound, have rock along much of their shorelines.

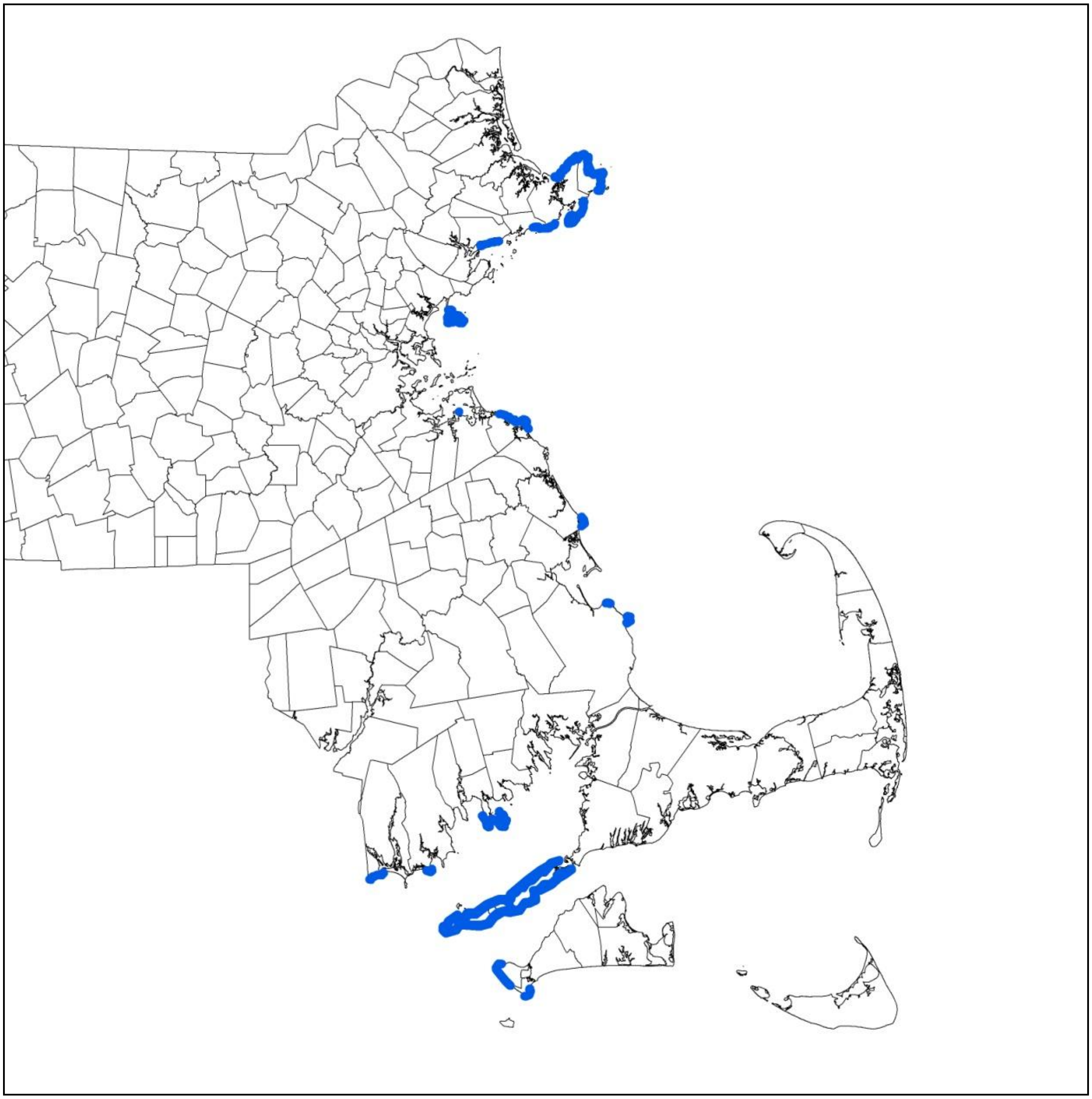


Figure 4-38: Locations of Major Rocky Points and Coastlines in Massachusetts.

Species of Greatest Conservation Need on Rocky Coastlines

Four SGCN are assigned to the Rocky Coastlines habitat (Table 4-31).

Very large flocks of Long-tailed Ducks and Common Eiders winter on Massachusetts' offshore waters (see the section on Marine and Estuarine Habitats), and smaller flocks of these two species feed inshore, often along rocky coastlines. Inshore flocks of Common Eiders can range up to a thousand or more birds, while the maximum number of Long-tailed Ducks in near-shore flocks tends to be an order of magnitude smaller. Occasionally, all of these birds may mingle at a single site, but in general the flocks tend to consist of a single species.

Long-tailed Ducks do not breed in Massachusetts, but Common Eiders are now well established as a nesting bird. In the early 1970s, Common Eider chicks from Maine were released on Penikese Island and some of these bred on the island in subsequent years. From this beginning, Common Eiders first spread to breed on the nearby Elizabeth Islands. Since then nesting eiders have moved west onto small islands in Buzzards Bay and become common nesters on Boston Harbor islands, notably Calf Island and outer Brewster Island. A few additional birds nest on islands off Cape Ann and are now a relatively common nester along rocky coastlines in the state.

Small flocks of Harlequin Ducks, up to about 30 birds at a site, winter along Massachusetts' rocky coastlines, but the species does not breed in the state. According to Veit and Petersen (1993), traditional wintering sites for Harlequin Duck include "the rocks off the Hammond Castle in Magnolia, the Glades at North Scituate, the east shore of Cape Cod at East Orleans, and the Squibnocket Cliffs at Martha's Vineyard. Generally, they prefer rocky, granitic shores such as those at Cape Ann; however, on Cape Cod and the Islands, they frequent stretches of beach where only scattered rocks exist." The North American wintering population of eastern Harlequins winters from southern Labrador to as far south as New Jersey, but most flocks consists of only a few birds. Between 1997 and 2002, the eastern population was estimated at only 1,575 to 1,800 birds with about three-quarters wintering in Maine. However, this is up from an estimate of fewer than 1,000 birds at the end of the 1980s. In recent years, the population appears to be increasing and its range expanding, but current numbers are still believed to be below historical levels.

Other birds that feed or nest along rocky coastlines in Massachusetts include Common and Red-throated loons; Horned and Red-necked grebes; Great and Double-crested Cormorants; White-winged, Black, and Surf scoters; Purple Sandpipers; and Great Black-backed, Herring, Ring-billed, and other gulls, as well as a number of other birds in smaller numbers.

Massachusetts allows hunting of Common Eider and Long-tailed Ducks, with a current daily bag limit of 7 sea ducks (scoters, eiders, and Long-tailed Duck combined), and a possession limit of 21 sea ducks. In 1999, Massachusetts reduced the bag for eiders from seven birds to four, with a limit of one hen. Hunting of Harlequin Ducks is not allowed in the Atlantic Flyway. In 2013-2014, the season for both Common Eider and Long-tailed Ducks was open October 7 to January 31.

Table 4-31: Species of Greatest Conservation Need on Rocky Coastlines

Taxon Grouping	Scientific Name	Common Name
Birds	*Calidris maritima*	Purple Sandpiper
	Clangula hyemalis	Long-tailed Duck
	Histrionicus histrionicus	Harlequin Duck
	Somateria mollissima	Common Eider

Threats to Rocky Coastlines

IUCN Threat 1: Residential and Commercial Development
Residential and commercial development is not a significant threat to SGCN of rocky coastlines in Massachusetts.

IUCN Threat 2: Agriculture and Aquaculture
Aquaculture along Massachusetts rocky coastline is limited. However, eiders have been accused of depredations on shellfish beds, including native beds commercially exploited by humans.

Common Eiders also die as a result of entanglement in fishing and aquaculture nets (Hoopes 1992). Nets are also documented as a source of mortality for Long-tailed Ducks, at least on the Great Lakes (Robertson and Savard 2002).

IUCN Threat 3: Energy Production and Mining
Wind-turbine installations cause mortality to birds and may alter and reduce habitat available for foraging. The Cape Wind Project proposed and approved in Nantucket Sound more than 10 years ago has still not been developed. Concern for the effects on Long-tailed Ducks roosting in the Sound appears to be misplaced, as a study conducted by Mass Audubon did not find heavy use of the proposed area by satellite-tagged ducks. However, data is limited, and habitat-use patterns of sea ducks may change over time. Another potential threat is from sand mining of nearshore areas, which could reduce foraging habitat and prey for sea ducks.

IUCN Threat 4: Transportation and Service Corridors
Regular oil barge traffic occurs along the Massachusetts coast and the potential for spills is a constant threat to sea ducks.

IUCN Threat 5: Biological Resource Use
Hunting has been identified as possibly contributing to the long-term decline of Common Eider and, possibly, Long-tailed Duck numbers (Goudie et al. 2000, Robertson and Savard 2002). It is unclear if hunting of sea ducks in Massachusetts is a major contributor to sea-duck declines. For the 5 years between 2009 and 2013, Massachusetts averaged just 960 active sea-duck hunters with an average annual bag of 7.24 sea ducks of all species. The most recent estimates of sea-duck harvests for Massachusetts are in Table 4-32, below. These estimates are based on USFWS Harvest Information Program (H.I.P.) survey results. The confidence limits for any given year are broad, but the average over several years may give a reasonable idea of general harvest levels.

Currently, the USFWS is considering whether a special sea-duck-hunting zone is still valid. Such special seasons were designed for underutilized or overabundant species. There is a question whether this applies any longer to sea ducks, as sea-duck hunting has increased in popularity and populations in general appear to be declining.

Table 4-32. Annual Harvest of Sea Ducks in Massachusetts

Year	Long-tailed Duck	Common Eider
2010	100	5000
2011	100	5700
2012	400	5800
2013	200	3500

IUCN Threat 6: Human Intrusions and Disturbance
More likely threats to these species are the detrimental effects of overharvesting of their prey species, coastal pollution, and disturbance of wintering flocks or nesting pairs by human activities (Goudie et al. 2000). These activities include recreational and commercial boating along the coast, hikers and other recreationalists on land immediately along the shore, and the erection of structures such as docks, seawalls, and wind turbines. An occasional threat will be oiling and subsequent mortality of these species during oil spills. Oil spills during the winter months could have a very large impact on these birds, as there is a significant potential for a spill to intersect with large flocks of wintering birds at that time.

Although rocky coastlines have occasionally been quarried for use as building material, it is unlikely that this currently poses much of a deleterious impact on wintering sea ducks feeding along these coasts.

Excessive mortality of adult Common Eiders, Long-tailed Ducks, and most other sea ducks is of concern, because of the life history strategies of these species: they take longer to reach sexual maturity than other ducks; there is a low survival rate of eggs, chicks, and first-year birds; and not all adults of reproductive age attempt nesting every year (Goudie et al. 2000, Robertson and Savard 2002). With such a life history strategy (as in Blanding's and other turtles), rates of adult mortality as low as a few percent per year can lead to long-term population declines.

IUCN Threat 7: Natural System Modifications
Natural system modifications are not a threat to the rocky coastlines of Massachusetts

IUCN Threat 8: Invasive and Other Problematic Species and Genes
Since 1998, the Wellfleet Bay Virus (WFBV) has played a role in the death of a variable number of Common Eiders annually. Each year, hundreds to thousands of eiders wash up on the shores of Cape Cod in late summer or fall, and many of these birds were found to have contracted the WFBV among other afflictions. First discovered on Cape Cod, the virus has also been found in eiders from Canada. Although the source remains unclear, there is a theory that the disease is tick-borne.

IUCN Threat 9: Pollution
Oil spills and other pollutants are a major threat to coastal systems, as noted above.

IUCN Threat 10: Geological Events
Geological events are not a threat to rocky coastlines in Massachusetts, at least in the near future.

IUCN Threat 11: Climate Change and Severe Weather
Sea-level rise may result in the loss of small islands where eiders nest. An increase in severe-weather events as the climate changes may increase storm surges, causing reduced nesting success by Common Eiders and erosion of cobble shorelines.

Conservation Actions

Direct Management of Natural Resources
This potential conservation action is not warranted for this habitat.

Data Collection and Analysis
Conduct annual surveys for Long-tailed Duck (wintering) and Common Eider (wintering and breeding) to determine their range, abundance, and distribution in the state. Additional research is needed to improve our understanding of Wellfleet Bay Virus and its effects on the eider population.

Conduct systematic surveys for wintering Harlequin Ducks, which are not easily surveyed from the air.

Research the natural history of animals using rocky coastlines, with attention to any impacts to food sources and to possible deleterious effects of human uses of these coasts and the immediately adjacent waters.

Improve the accuracy of estimates for the numbers of harvested sea ducks in Massachusetts.

Education and Outreach
Educate and inform the public about the values of rocky coastline habitats and the issues related to their conservation, through agency publications and other forms of public outreach in order to instill public appreciation and understanding.

Harvest and Trade Management
Investigate potential relationships between sea-duck harvest and sea-duck decline so that appropriate management actions can be undertaken if warranted.

Land and Water Rights Acquisition and Protection
Protect rocky coastlines supporting populations of rare and uncommon animals from onshore development; excessive recreational use; and construction of docks, piers, jetties, and other structures in the water near shore.

Take the use of areas by seabirds into account when siting lease areas for aquaculture, wind-energy facilities, and other uses.

Law Enforcement
This potential conservation action is not warranted for this habitat.

Law and Policy
Support legislation to minimize the chances of catastrophic oil spills.

Planning
Develop detailed conservation and recovery plans for SGCN associated with rocky coastlines. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Species Reintroduction and Stocking
This potential conservation action is not warranted for this habitat.

Rock Cliffs, Ridgetops, Talus Slopes, & Similar Habitats

Habitat Description

This habitat type is a composite of several separate and distinctive natural communities, but often these natural communities are adjacent to each other (e.g., a rock cliff may have a talus slope below it and a rocky ridgetop or open rock outcroppings above it). The animals of conservation concern associated with these different natural communities may inhabit some or all of these adjacent rocky habitats, and may move amongst them over the course of a day or a season.

In Massachusetts, rock cliffs, talus slopes, and rocky ridgetops and outcroppings may be of acidic, circumneutral, or calcareous bedrock, and may be open to the sun or partially to mostly shaded by woodland forest. Often there is little soil, in part because of steepness and rapid erosion, but also because these areas are likely to be well-drained, open to the drying effects of wind and sun, and subject to more frequent and extensive fire than lowland areas. Small fires started by lightning or people in these rocky areas often spread both more quickly and further than similar fires in lowlands because the litter in rocky areas is drier, fire moves uphill faster than on level ground, and fire suppression is more difficult due to the relative inaccessibility of the habitat. Wind storms, ice storms, and boulder slides also influence tree-canopy cover and other aspects of vegetation structure and composition on ridgetops and talus slopes.

Rocky areas, especially cliffs, ridgetops, and talus slopes, are not particularly suitable for agriculture or forestry. Historically, therefore, these habitats have not been plowed or subjected to as much tree cutting or grazing as less steep or rocky areas. As a result, cliffs, ridgetops, and talus slopes have in some cases served as habitat refugia for some species of animals and plants.

Bedrock outcrops may be hard enough to have withstood the scouring of glaciers, or may be soft enough that a river slowly but continuously created cliffs and ledges as the bedrock eroded. An example of rock cliffs composed of resistant bedrock is the basalt of the Mt. Tom range in the Connecticut River Valley.

These basalt layers slant upward to the west. Glaciers eroded softer rock from the top and west side of the basalt, leaving a sheer cliff on the west side of the mountain, with a large talus slope below the cliff and a rocky ridgetop above. Further north in the Connecticut River Valley, the soft red sandstone of North and South Sugarloaf mountains was substantially eroded during glaciation, but it is likely that the east-facing sandstone cliff of South Sugarloaf resulted from the Connecticut River cutting through the rock during the draining of glacial Lake Hitchcock.

See Swain and Kearsley (2015) for more detail on rocky-area natural communities recognized in Massachusetts, including acidic, circumneutral, and calcareous rock cliffs; rocky summit/rocky outcrops; and open talus/boulder fields.

Rock cliffs, talus slopes, and rocky ridgetops and outcrops are found throughout much of Massachusetts (see Figure 4-39), with the exception of southeastern Massachusetts (including Cape Cod and the offshore islands). Worcester County has many rolling hills, with only a few areas of rock cliffs, ridgetops, and talus slopes, while Berkshire County and the western parts of Franklin, Hampshire, and Hampden counties are more mountainous and have more of these rocky habitats than the rest of the state.

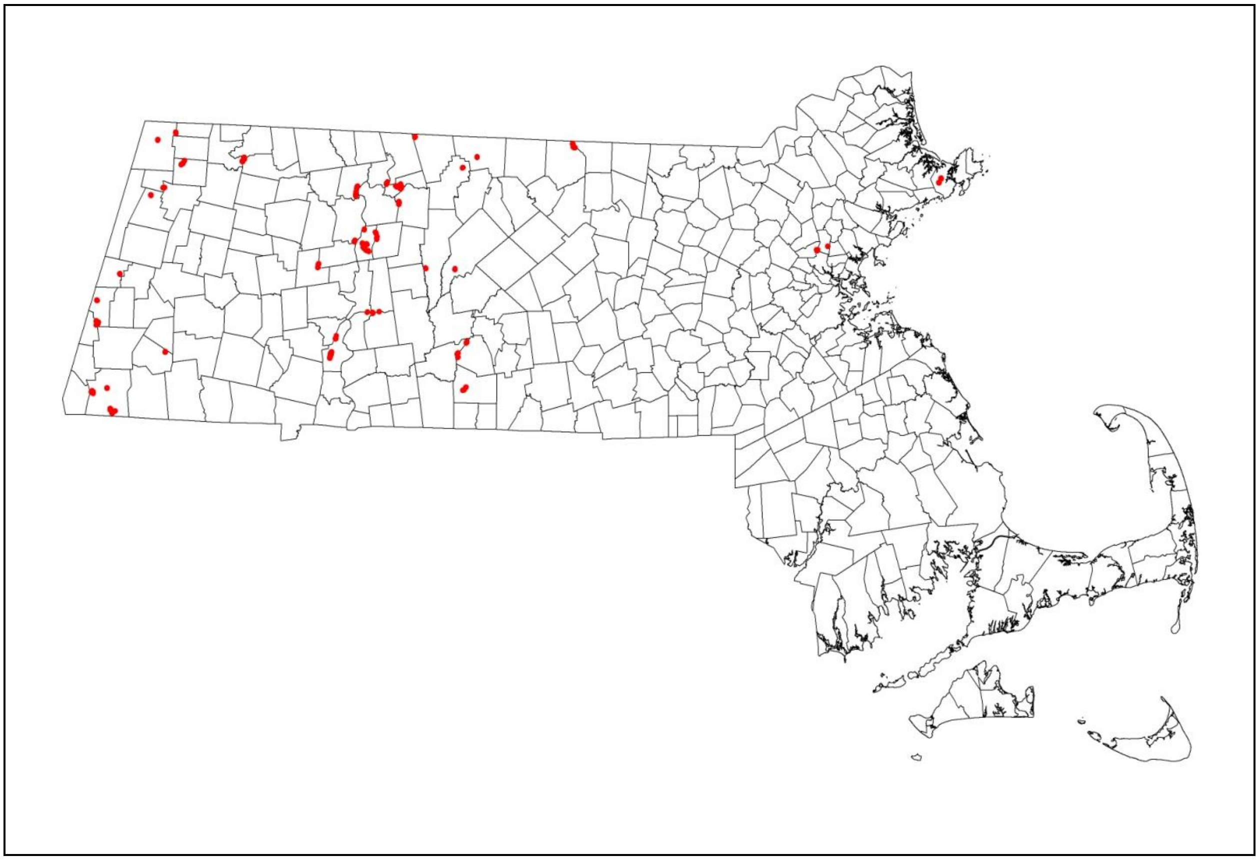


Figure 4-39: Locations of Some Rocky Cliffs, Ridgetops, Talus Slopes, and Similar Habitats in Massachusetts.

Species of Greatest Conservation Need in Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats

Sixty-five SGCN are assigned to Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats (Table 4-33).

In Massachusetts three state-listed species of snakes, the Eastern Ratsnake, Copperhead, and Timber Rattlesnake, are primarily inhabitants of rocky areas and surrounding forest. Copperheads and Timber Rattlesnakes will use a communal den ("hibernaculum"), and are sometimes joined by Eastern Milksnakes (*Lampropeltis triangulum*). North American Racers (*Coluber constrictor*), Eastern Gartersnakes (*Thamnophis sirtalis*), and Ring-necked Snakes (*Diadophis punctatus*) also may overwinter in a communal den. Such dens are usually located in crevices in south- or west-facing talus slopes. Talus slopes offer good drainage and passageways to deep underground chambers where temperatures remain stable and above freezing during even the harshest winters. While dens can be located in other habitats, in Massachusetts, talus slopes are the usual location for winter snake dens. Most snakes in these habitats overwinter from mid-October through April, and rely on fat stores to survive the winter.

Historically, Peregrine Falcons nested on natural cliffs in Massachusetts. About 14 such historical Peregrine nesting sites ("aeries") have been identified, but currently almost all Peregrine nests are on tall buildings or large bridges above major rivers. In 2002, a pair of Peregrines nested on a natural cliff for the first time since the mid-1900s. That nesting attempt failed and the pair did not attempt to nest at the same site in 2003. However, that year a pair (possibly the same pair) nested successfully on a natural cliff elsewhere in the Connecticut River Valley. Several historical aeries still appear suitable for Peregrine nesting, and may be occupied in the future. While the number of nesting pairs of Peregrine Falcons has rebounded in Massachusetts over the past two decades (from one or two pairs prior to 1996 to 24 pairs in 2014), numbers have yet to reach historical levels, and additional natural aeries may be recolonized in the future. It is likely, however, that rock climbers and Great Horned Owls sufficiently disturb Peregrines to keep the birds from nesting at some sites.

In the coniferous forests of Berkshire County, Rock Shrews inhabit shaded, cool talus slopes and crevices in rock cliffs and outcroppings. Often these sites are hemlock ravines or old-growth forests with abundant mosses and lichens. In addition to obvious habitat alterations such as development or heavy logging, hemlock die-off due to Wooly Adelgid infestation may render these areas unsuitable for Rock Shrews.

At the other end of the state, Hentz's Red-bellied Tiger Beetle is found on the tops of granite hills around Boston (Leonard and Bell 1999), often in parks established more than 100 years ago. These beetles prefer open rock outcrops and prey on small invertebrates. Development of these hilltops or overuse by hikers and picnickers can destroy or degrade the habitat of this species.

In Massachusetts, three state-listed moths are found in rocky areas. It is probable that these moths were more widespread when the landscape was more open prior to modern fire-suppression practices. Now these moths are restricted to rocky habitats still subject to occasional fire. The caterpillars of each of them feed on specific plants: Herodias Underwing larvae eat Scrub Oak (*Quercus ilicifolia*), Slender Clearwing larvae eat Lowbush Blueberry (*Vaccinium* spp.), and Orange Sallow larvae eat the flowers and unripe seed pods of False Foxgloves (*Aureolaria* spp.). All of these plants thrive following fire, responding with vigorous growth and increased seed production and dispersal.

Many common animals use rock cliffs, ridgetops, and talus slopes for nesting or denning, including the Common Raven (*Corvus corax*), Black Vulture (*Coragyps atratus*), Turkey Vulture (*Cathartes aura*), Porcupine (*Erethizon dorsatum*), Coyote (*Canis latrans*), and a variety of small rodents. Other animals of conservation concern that use these areas are the Bobcat (*Lynx rufus*), Marbled Salamander (*Ambystoma opacum*), and bats.

Rocky cliffs, ridgetops, and talus slopes are refugia to several of Massachusetts' rarest plant species. Some of these plants, such as the fir-mosses, are at the southern end of their ranges and only occur on north-facing slopes. Some, such as Black-fruited Woodrush, Rand's Goldenrod, Large-leaved Goldenrod, Mountain Cranberry and Northern Mountain-ash, only occur at high elevations in Massachusetts (over 2000 feet). Several of the plants of greatest conservation need associated with these habitats, including Snowberry, Narrow-leaved Vervain, False Pennyroyal, Drooping Speargrass, Hairy Beardtongue, and Michaux's Sandwort, are specialists on calcareous or circumneutral rock, and require openings in the canopies in these areas. Large-leaved Sandwort is found only in association with serpentine rock in Massachusetts, while Small-flowered Buttercup is a specialist on basalt and other mafic rocks. Fire has been important to maintain the habitat for several of the rare plants as well. Lion's Foot, Lesser Snakeroot, New England Blazing Star, and New England Northern Reed Grass are particularly fire-adapted. Many of the plants of greatest conservation need in this community are associated with seeps on cliffs or at the base of cliffs and talus, including Climbing Fumitory, Bartram's Shadbush, Mountain Spleenwort, Wall-rue Spleenwort, Appalachian Bristle-fern, Fragile Rock-brake, American Twinflower, Small Dropseed, Bristly Black Currant, Smooth Woodsia, and Mountain Cranberry.

Table 4-33: Species of Greatest Conservation Need in Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats

Taxon Grouping	Scientific Name	Common Name
Reptiles	*Agkistrodon contortrix*	Copperhead
	Coluber constrictor	North American Racer
	Crotalus horridus	Timber Rattlesnake
	Pantherophis alleghaniensis	Eastern Ratsnake
Birds	*Falco peregrinus*	Peregrine Falcon
	Petrochelidon pyrrhonota	Cliff Swallow
Mammals	*Sorex dispar*	Rock Shrew
Beetles	*Cicindela rufiventris hentzii*	Hentz's Red-bellied Tiger Beetle
Lepidoptera	*Catocala herodias gerhardi*	Herodias Underwing
	Hemaris gracilis	Slender Clearwing
	Pyrrhia aurantiago	Orange Sallow
Plants	*Adlumia fungosa*	Climbing Fumitory
	Ageratina aromatica	Lesser Snakeroot
	Agrimonia pubescens	Hairy Agrimony
	Amelanchier bartramiana	Bartram's Shadbush
	Amelanchier sanguinea	Roundleaf Shadbush
	Arabidopsis lyrata	Lyre-leaved Rock-cress
	Asclepias purpurascens	Purple Milkweed
	Asclepias verticillata	Whorled Milkweed
	Asplenium montanum	Mountain Spleenwort
	Asplenium ruta-muraria	Wall-rue Spleenwort
	Boechera laevigata	Smooth Rock-cress
	Calamagrostis stricta ssp. *inexpansa*	New England Northern Reed Grass
	Calystegia spithamaea	Upright False Bindweed
	Carex glaucodea	Glaucescent Sedge
	Carex oligocarpa	Rich Woods Sedge
	Celastrus scandens	American Bittersweet
	Cerastium nutans	Nodding Chickweed
	Chenopodium foggii	Fogg's Goosefoot
	Clematis occidentalis	Purple Clematis
	Crepidomanes intricatum	Appalachian Bristle-fern
	Cryptogramma stelleri	Fragile Rock-brake
	Cyperus houghtonii	Houghton's Flatsedge
	Cystopteris laurentiana	Laurentian Bladderfern
	Desmodium cuspidatum	Large-bracted Tick-trefoil
	Houstonia longifolia	Long-leaved Bluet
	Huperzia appressa	Appalachian Fir-moss
	Huperzia selago	Mountain Fir-moss
	Liatris novae-angliae	New England Blazing Star
	Linnaea borealis ssp. *americana*	American Twinflower
	Lonicera hirsuta	Hairy Honeysuckle
	Luzula parviflora ssp. *melanocarpa*	Black-fruited Woodrush
	Minuartia michauxii	Michaux's Sandwort
	Moehringia macrophylla	Large-leaved Sandwort
	Nabalus serpentarius	Lion's Foot
	Oligoneuron album	Upland White Goldenrod
	Panax quinquefolius	American Ginseng
	Panicum philadelphicum ssp. *gattingeri*	Gattinger's Panic-grass
	Paronychia argyrocoma	Silverling
	Penstemon hirsutus	Hairy Beardtongue
	Poa saltuensis ssp. *languida*	Drooping Speargrass
	Ranunculus micranthus	Small-flowered Buttercup

Taxon Grouping	Scientific Name	Common Name
	Ribes lacustre	Bristly Black Currant
	Rosa acicularis ssp. *sayi*	Northern Prickly Rose
	Solidago macrophylla	Large-leaved Goldenrod
	Solidago simplex ssp. *randii* var. *monticola*	Rand's Goldenrod
	Sorbus decora	Northern Mountain-ash
	Sporobolus neglectus	Small Dropseed
	Symphoricarpos albus var. *albus*	Snowberry
	Trichostema brachiatum	False Pennyroyal
	Trisetum spicatum	Narrow False Oats
	Vaccinium vitis-idaea ssp. *minus*	Mountain Cranberry
	Verbena simplex	Narrow-leaved Vervain
	Viburnum rafinesquianum	Downy Arrow-wood
	Woodsia glabella	Smooth Woodsia

Threats to Rock Cliffs, Ridgetops, Talus Slopes, and Similar Habitats

IUCN Threat 1: Residential and Commercial Development

At present, a large proportion of the rock cliffs, ridgetops, talus slopes, and similar rocky habitats in Massachusetts occur in state parks, state forests, or on other conservation land. Therefore, many of these habitats are not threatened by residential and commercial development. Where these habitats do not occur on conservation land, development is more difficult (and therefore more costly) as compared to development in areas with more level topography. As a result, historically there has been little development of steep, rocky habitats.

However, this is currently changing in the highly developed eastern and central parts of Massachusetts, where undeveloped land is at a premium. A recent development trend is to remove the summit of a rocky hilltop by blasting and removal of rock, followed by filling and bulldozing to flatten the hilltop, upon which a shopping complex and/or housing is then built. Access is created by constructing (typically following blasting and rock removal) an access road that winds around the hill so that the grade is not too steep. Examples of recent developments constructed with these methods in central Massachusetts, each consuming an entire hill, include The Shoppes at Blackstone Valley in Millbury, Northborough Crossing in Northborough, and the Highland Commons Shopping Center in Berlin.

Areas with steep topography (and rock cliffs, ridgetops, talus slopes, and other rocky habitats) are often prime locations for downhill skiing. While not development in the typical sense, downhill-skiing facilities have infrastructure, including access roads, ski slopes, and lifts, which requires some degree of habitat modification. Therefore, installation of new, or the expansion of existing, downhill-ski areas may threaten rock cliffs, ridgetops, talus slopes, other rocky habitats, and the animals and plants that inhabit them.

Some conservation lands owned by the state with steep topography and rock cliffs, ridgetops, talus slopes, and/or other rocky habitats, also have downhill ski areas. Examples include Wachusett Mountain Ski Area in Princeton and the Blue Hills Ski Area in Canton. While some consider downhill skiing to be passive recreation, access roads, ski slopes, and lifts are still required, necessitating some degree of habitat modification.

IUCN Threat 2: Agriculture and Aquaculture

In Massachusetts, from colonial settlement through the mid-1800s, land was extensively cleared for various agricultural activities (Foster and Aber 2004). However, due to the steep topography and generally poor soils of rock cliffs, ridgetops, talus slopes, and other rocky habitats, these areas were significantly less impacted. Agriculture has greatly declined in the state since the mid-1800s (Foster and Aber 2004), even in lowland areas, and currently occurs at too small a scale to constitute a significant threat to rock cliffs, ridgetops, talus slopes, and other rocky habitats.

Some rocky uplands in Massachusetts may be cleared for firewood, and cleared areas may subsequently be used as pastures for grazing livestock. However, such activities have greatly declined in the state since the mid-1800s (Foster and Aber 2004), and currently occur at too small a scale to constitute a significant threat to rock cliffs, ridgetops, talus slopes, and other rocky habitats.

In Massachusetts, there is potential for tree harvest at a commercial scale for the wood-pulp or biofuel industries, but such threats have not yet manifested.

IUCN Threat 3: Energy Production and Mining
A significant threat to rocky habitats in Massachusetts is quarrying. Several types of quarrying are likely to destroy habitat for animals and plants in areas with rock cliffs, ridgetops, talus slopes, and other rocky habitats, including basalt (traprock) and sandstone quarries on the ridges of the Connecticut River valley, limestone and marble quarries in the Berkshires, and granite quarries in much of the state from Boston westward. Rock quarrying removes existing vegetation along with underlying rocks. This causes changes in future vegetation, habitat characteristics, and hydrology. Some quarrying creates spoils, or talus-like areas with exposed rock and consequently altered vegetation and habitat. In serpentine areas, quarrying may expose previously buried toxic material.

Quarrying for stone and gravel poses a direct threat of mortality for a number of species, including the Eastern Ratsnake and Copperhead. When quarries are abandoned, they may eventually revert to habitat suitable for species like Hentz's Red-bellied Tiger Beetle. However, just as often, mined or quarried areas are left bare of all but planted grass and invasive weeds – land ripe for residential or commercial development.

Rocky summits and ridgetops are desirable locations for the installation of wind turbines. Most wind-turbine installations have a relatively small habitat footprint once installed. However, the process of installation includes creating access for heavy equipment, which typically causes more extensive habitat alteration, at least in the short term. Such temporary alteration can be followed by habitat restoration, but proven restoration methods, further tailored to site-specific concerns, are often necessary to insure success. Otherwise, long-term effects, such as creation of inroads for invasive exotic plant species, may result.

IUCN Threat 4: Transportation and Service Corridors
Roads and railroads are often routed so as to avoid steep terrain, and therefore seldom traverse areas with rock cliffs, ridgetops, talus slopes, and other rocky habitats. However, it is occasionally necessary to route a new road or railroad through an area with steep topography, often involving blasting and stone removal, which poses threats similar to those discussed under Energy Production and Mining, above. In addition, roads that traverse talus slopes and other rocky habitats introduce the threat of road mortality for animals such as snakes.

Utility rights-of-way may traverse rock cliffs, ridgetops, talus slopes, and other rocky habitats, and the maintenance of rights-of-way may create open, disturbance-dependent habitat. Maintenance of utility rights-of-way may benefit some species, but at the same time be detrimental, or of no consequence, to other species. The effects of utility right-of-way management on populations of species are complex, and depend on the specific location, the species in question, and the particular management methods and timing.

IUCN Threat 5: Biological Resource Use
American Ginseng often grows in steep, rocky habitats. Roots of the Ginseng plants are used in folk medicine as a stimulant or aphrodisiac, and are an ingredient in some energy drinks and herbal teas. Because American Ginseng is listed as a Species of Special Concern in Massachusetts, it is illegal to harvest wild plants; however, some degree of harvest does occur.

White Pine Blister Rust (*Cronartium ribicola*), a fungal pathogen of five-needle (white) pines, was introduced to the northeastern U.S. around 1900. White Pine Blister Rust requires two host species to complete its life cycle, with the second host typically a species of currant or gooseberry (*Ribes* spp.). In an effort to control spread of the disease and subsequent white-pine mortality, a *Ribes* eradication program was enacted throughout much of the northeastern U.S. from 1917 until the late 1970s. Therefore, the current rarity of Bristly Black Currant, a Species of Special Concern in Massachusetts that grows in steep, rocky habitats, may partly be the result of 20th-century efforts to control White Pine Blister Rust.

In areas with rock cliffs, ridgetops, talus slopes, and other rocky habitats, trees, when present at all, tend to be stunted or of otherwise poor quality, precluding timber harvest for the purpose of lumber production. Trees may still be harvested for firewood, but such harvest is typically on too small a scale to constitute a significant threat.

IUCN Threat 6: Human Intrusions and Disturbance
With the important exception of downhill skiing (discussed under Residential and Commercial Development, above), in areas of rock cliffs, ridgetops, talus slopes, and other rocky habitats, human recreation is largely restricted to trail use. Hiking is the most common use of trails, but hiking trails may also be used, either legally or illegally, by riders of mountain bikes, off-road vehicles, and snowmobiles, all of which may cause damage to trails and the habitat along them. Such damage may include crushing of vegetation (including rare plants and larval host plants of rare moths inhabiting these areas), soil erosion, and alteration of natural water-runoff patterns. In conservation lands with existing trails, it is not uncommon for people to create additional, unpermitted trails that exacerbate detrimental habitat impacts.

Trails along ridgetops or talus slopes increase the probability that people will encounter large-bodied snakes, including Copperheads, Timber Rattlesnakes, and Eastern Ratsnakes, and purposeful snake mortality may result (see Biological Resource Use, above). For this reason, trails near den sites for these snakes are especially problematic. Even well-meaning visitors to known snake dens (for example, photographers) may unintentionally threaten snakes by spreading disease.

Cliffs attract rock climbers and B.A.S.E. jumpers. Peregrine Falcons nesting on such cliffs may be sufficiently disturbed to abandon these sites, either just for a season or indefinitely.

For the large and poisonous snakes in this habitat, there can be significant issues from humans: enthusiastic aficionados harass them, fearful individuals seek them out with harm in mind, unprepared people kill them out of fear, and collectors seek to place them into the pet trade. In Massachusetts, there are documented cases of snakes being killed in residential neighborhoods and along trails (NHESP database; Tom French and Tom Tyning, pers. comm.). Many others are likely killed without knowledge of which species they are, but this has contributed to the critical imperilment of the species.

IUCN Threat 7: Natural System Modifications
As discussed in the habitat description for this section, both the edaphic characteristics and the topography of steep, rocky areas render them prone to wildfire. While fire suppression is more difficult in these habitats than elsewhere, it is still often effective, and many of these habitats burn less frequently than would be desirable to maintain habitat characteristics favored by many plants and animals of conservation concern.

IUCN Threat 8: Invasive and Other Problematic Species, Genes, and Diseases
Over the past two decades, infection with *Chrysosporium* fungal disease has been an increasing problem affecting snake species, including Timber Rattlesnake, Copperhead, Eastern Ratsnake, and Black Racer.

IUCN Threat 9: Pollution
As discussed under Human Intrusions and Disturbance above, hiking is a popular recreational activity in areas of rock cliffs, ridgetops, talus slopes, and other rocky habitats. Unfortunately, less-considerate hikers, or others that use trails through these habitats, may litter. Trails that are accessible to vehicles (whether legally or not) make the habitat vulnerable to trash dumping.

Atmospheric acidification, and acid rain in particular, is a threat to a variety of habitat types in the eastern United States, including in Massachusetts. Acid rain may adversely affect soil chemistry, soil biology, plants, and the animals dependent upon healthy soil and vegetation. The adverse effects of acid rain are greater at higher altitude because these areas are more frequently exposed to clouds and fog, which are more acidic than rain. Therefore, atmospheric acidification can be a serious threat to plants and animals inhabiting high-elevation rock cliffs, ridgetops, talus slopes, and other rocky habitats.

IUCN Threat 10: Geological Events
In Massachusetts, geological events occasionally pose a threat to rock cliffs, ridgetops, talus slopes, and other rocky habitats, or to the animals and plants that inhabit

them, as rocks set in motion by small earthquakes or avalanches may bury or destroy sites supporting these species. As the cliffs and talus slopes are formed, in many cases, by these small geological events, in general these events are not a significant threat. However, if development or other threats have destroyed nearby populations that could serve as sources for recolonization of altered sites, then even small rock slides could have the effect of wiping out all or most of a particularly rare species within the state.

IUCN Threat 11: Climate Change and Severe Weather
Global warming is a known threat to montane plants and animals that live only at higher elevation because they are adapted to a cooler climate. While there are no truly high-elevation areas in Massachusetts, the highest peaks in the state (including the highest, Mount Greylock, at 1,064 meters) include some of the most important rock cliffs, ridgetops, talus slopes, and other rocky habitats. Some SGCN species in Massachusetts, as well some more common species, inhabit high-elevation rock cliffs, ridgetops, talus slopes, and other rocky habitats in part due to the cooler climate. These species are particularly vulnerable to climate warming.

Conservation Actions

Direct Management of Natural Resources
Perhaps the greatest management needs for rock cliffs, ridgetops, talus slopes, and other rocky habitats are prescribed fire (sometimes in combination with mechanical cutting) and manual removal or control of invasive exotic vegetation. In combination, these two management activities promote native-plant communities (in terms of both species composition and structure), which in turn promote the persistence of animal species that depend on native plants in rocky habitats. One benefit of prescribed fire is the promotion of open habitat vegetated with shrubs such as Scrub Oak (*Quercus ilicifolia*) and lowbush blueberry (*Vaccinium* sp.), which provide larval host plants for moths like the Herodias Underwing and Slender Clearwing (Wagner et al. 2003). These same plants provide acorns and blueberries, both important food sources for a variety of mammals and birds, including small mammals that in turn provide food for snakes such as the Copperhead and Timber Rattlesnake. In addition, many snake hibernacula and birthing rookeries are overgrown with vegetation; a lack of nearby open areas for basking places females at a disadvantage, as they need to travel further to find such resources.

On state-owned and other conservation lands, management of both trail access and trail condition is important. Trails that are themselves fragile (erosion-prone), as well as trails through important and fragile habitat areas, should not be open to motorized vehicles. Additionally, in areas where trash dumping is a problem, trails should be closed to vehicles. Trail closure by passive means alone (gates) is often inadequate, and active enforcement (ticketing, etc.) may be necessary. Unauthorized trails should be closed and restored to natural habitat.

Data Collection and Analysis
Some SGCN species are under-surveyed in Massachusetts, including species inhabiting rock cliffs, ridgetops, talus slopes, and other rocky habitats. Such species include Rock Shrew, Slender Clearwing, and a number of plants for which more information on within-state distribution, abundance, and conservation status is needed.

The Copperhead, Timber Rattlesnake, and Eastern Ratsnake are all Endangered in Massachusetts. However, information critical to effective conservation of these species is often unknown, including the location of important den sites and an understanding of seasonal movement patterns. One obstacle is that the most commonly used tracking technology, radio telemetry, has significant limitations due to the size of radio equipment relative to juvenile snakes, the necessity of invasive surgery to implant radio equipment, and the large amount of staff time needed to track and analyze radio data. Another important topic for further research is interaction between co-occurring snake species, and interaction between different age classes of the same species.

Fungal skin infections are threatening some populations of Timber Rattlesnakes in Massachusetts and other states. A Regional Conservation Need Grant funded collection of data on the extent of the infection across populations, in addition to other relevant information; these data collection efforts should be continued.

Education and Outreach
The unnecessary (and often illegal) killing of venomous and/or large-bodied snakes such as the Copperhead, Timber Rattlesnake, Eastern Racer, and Eastern Ratsnake needs to be countered with public education about what are appropriate versus inappropriate actions during encounters with these species.

Harvest and Trade Management
Continued law enforcement is important to prevent the illegal harvest of SGCN species such as the Peregrine Falcon and American Ginseng. Reduction in the harvest of wild American Ginseng may also be achieved through public education about the alternative of Ginseng cultivation.

Land and Water Rights Acquisition and Protection
At present, a large proportion of the rock cliffs, ridgetops, talus slopes, and similar rocky habitats in Massachusetts occur in state parks, state forests, or on other conservation land. Where these habitats do not occur on conservation land, additional land acquisition and protection is desirable, particularly at sites known to provide habitat for either a large number of SGCN species, or for particularly threatened SGCN species.

Law Enforcement
Massachusetts has three major, complementary, environmental protection laws, the Massachusetts Environmental Policy Act (MEPA), the Wetlands Protection Act (WPA), and the Massachusetts Endangered Species Act (MESA). The MESA protects species that are listed as Endangered, Threatened, or of Special Concern in Massachusetts, all of which are also SGCN species. The MESA is enforced by the DFW, which, through regulatory implementation, annually reviews over 2,000 projects or activities in known habitats of state-listed species.

Regulatory review under the MESA is one of the most effective ways to avoid, minimize, and/or mitigate threats to state-listed and SGCN species in areas of rock cliffs, ridgetops, talus slopes, and other rocky habitats. Such threats that are discussed above as they apply to these habitats and the species that depend on them include residential and commercial development, installation of new or expansion of existing downhill ski areas, commercial tree harvest for wood pulp or biofuel, quarrying for stone and gravel, installation of wind turbines, road and railroad construction, installation and maintenance of utility rights-of-way, killing or collecting of state-listed animals, gathering of state-listed plants, use of off-road vehicles where prohibited, rock climbing where prohibited, and trash dumping.

Law and Policy
As noted just above, Massachusetts has effective conservation laws and policies already in place. No new significant laws and policies are needed to protect this habitat.

Planning
Develop detailed conservation and recovery plans for SGCN associated with rocky cliffs and similar habitats. Conservation and recovery plans are essential blueprints for setting and achieving conservation objectives. Conservation plans should include detailed needs, actions, and schedules specific to each SGCN, as well as metrics to determine the effectiveness of each action and the overall impact on these SGCN populations.

Recreational activities of potential concern that are specific to areas of rock cliffs, ridgetops, talus slopes, and other rocky habitats include various types of trail use, including riding of motorized off-road vehicles, mountain bicycling, and hiking; downhill skiing; and rock climbing. Planning by all conservation organizations and agencies should include determining where trails, ski areas, and rock-climbing sites interfere with habitat for animals and plants of conservation concern, and considering further exclusion of motorized off-road vehicles where currently permitted, rerouting or seasonal closure of trails, directing rock climbers to less sensitive sites, and increasing educational programs for recreational users.

D: Highest-priority Habitat Areas

The twenty-four SWAP Habitats described above, if aggregated together, cover almost every undeveloped acre of the Commonwealth. The questions then are: Where are the highest-priority areas for conservation actions and why are those sites the highest-priority areas? The Massachusetts Chapter of The Nature Conservancy (TNC) and the NHESP of the DFW answered these questions with the recent production of *BioMap2* (Woolsey et al. 2010).

BioMap2

BioMap2 is a series of GIS layers, a written report, a technical report, and town-by-town reports for every municipality in the Commonwealth. NHESP and TNC developed *BioMap2* to protect the state's biodiversity in the context of projected effects of climate change. The project combined NHESP's 30 years of rigorously documented rare species and natural community data with spatial data identifying wildlife species and habitats that were the focus of the DFW's 2005 State Wildlife Action Plan. *BioMap2* also integrates TNC's assessment of large, well-connected, and intact ecosystems and landscapes across the state, incorporating concepts of ecosystem resilience to address anticipated climate-change impacts. For information on *BioMap2*, see the website: http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/land-protection-and-management/biomap2/biomap2-town-reports.html

The *BioMap2* GIS layers and reports are intended to inform land-protection and stewardship efforts by all conservation organizations – state, regional, and local – working within Massachusetts. The project identified two types of high-priority areas:

- Core Habitats: 1.2 million acres (24% of the state) that are critical for the long-term persistence of rare species, as well as a wide diversity of natural communities and intact ecosystems.
- Critical Natural Landscapes: 1.8 million acres (34% of the state) complementing (and sometimes overlapping) Core Habitat, including large blocks of landscapes that provide habitat for wide-ranging native species, support intact ecological processes, maintain connectivity among habitats, and enhance ecological resilience. Critical Natural Landscapes also include buffer areas around coastal, wetland, and aquatic Core Habitats to help ensure their long-term integrity.

See Figures 4-40 and 4-41 for the locations of the *BioMap2* Core Habitats and Critical Natural Landscapes. See Chapter 2, Section E for more on *BioMap2*.

Together, Core Habitat and Critical Natural Landscape make up 40% of Massachusetts. About 41% of these *BioMap2* areas are permanently protected already. Protection and stewardship of Core Habitats and Critical Natural Landscapes are considered essential to safeguard the diversity of species and their habitats, intact ecosystems, and resilient natural landscapes across the Commonwealth. These areas are of the highest priority for conserving Species of Greatest Conservation Need.

The *BioMap2* GIS layers are available for free download here: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/biomap2.html.

The *BioMap2* summary report can be read or downloaded here: http://www.mass.gov/eea/docs/dfg/nhesp/land-protection-and-management/biomap2-summary-report.pdf.

The *BioMap2* technical report can be read or downloaded here: http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/land-protection-and-management/biomap2/biomap2-technical-report.html.

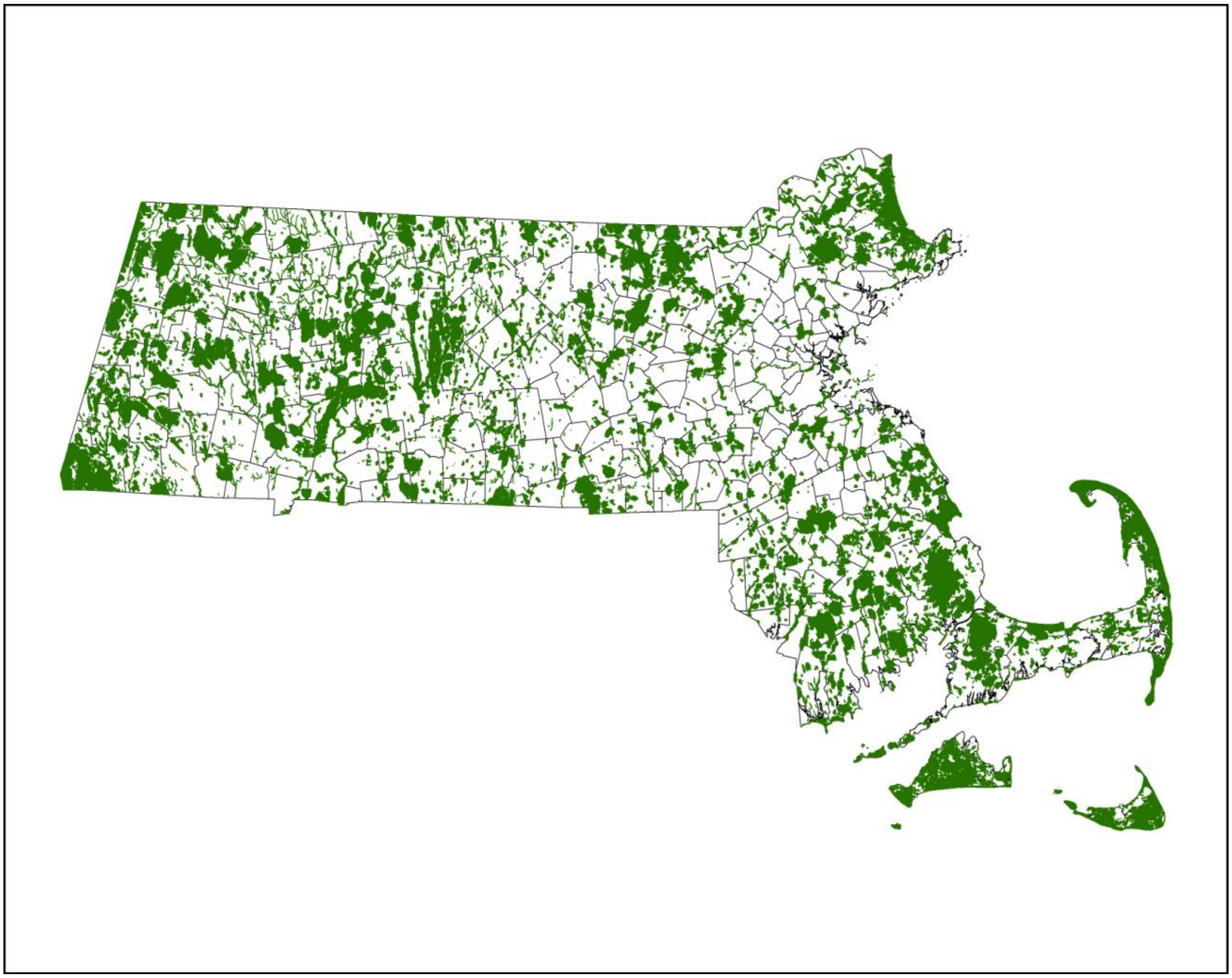


Figure 4-40: *BioMap2* Core Habitats.

Data from NHESP.

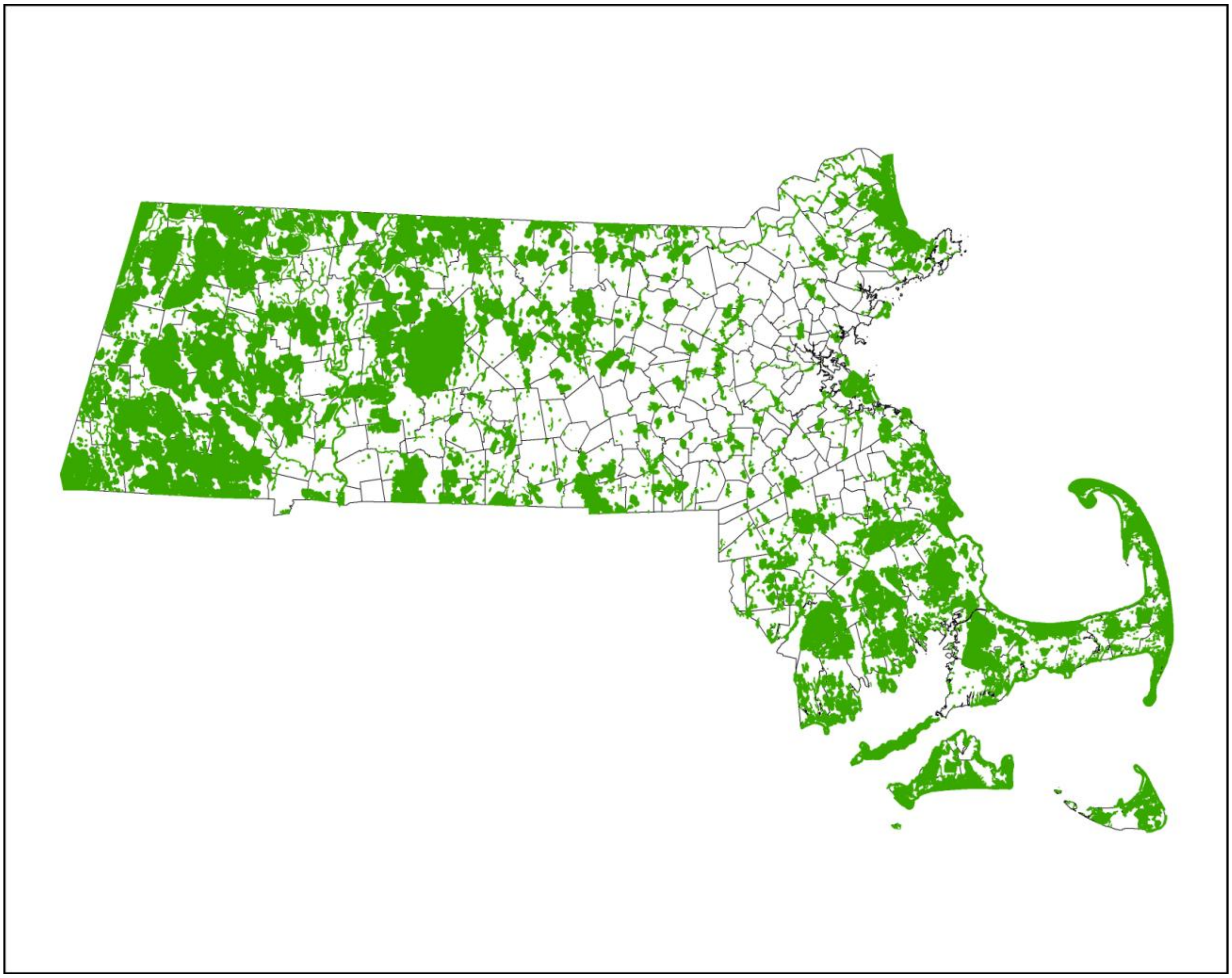


Figure 4-41: *BioMap2* Critical Natural Landscapes.

Data from NHESP.

Key Sites

BioMap2 is an informational resource for all conservation groups looking to conserve biodiversity in Massachusetts. However, the major state agencies charged with biodiversity conservation, the DFW and the DCR, have an additional tool to identify and target the most important sites – the Key Sites – for biodiversity protection and habitat management statewide. While the *BioMap2* areas cover about 40% of Massachusetts, the Key Sites within *BioMap2* cover 10% of the state's area.

These Key Sites were identified using three criteria. A Key Site needed to meet one or more of these thresholds:

1. Sites with a concentration of co-occurring rare species listed under MESA
2. Sites with the best-quality occurrences of high-priority species or natural communities (e.g., globally rare species)
3. Multiple, co-occurring, landscape-level resources, as identified by *BioMap2*

Explanation of the Three Key Sites Criteria

Multiple rare species occurrences

At some sites, MESA-listed and other SWAP species tend to co-occur, creating what can be called hotspots of biodiversity. Protecting and managing these hotspots that have a high richness of SWAP species is a highly efficient way to conserve multiple species, given limited funding and staff time. Therefore, one of the criteria for Key Site selection was sites where multiple SWAP species are documented.

A series of GIS analyses were conducted to determine where there were overlaps in the delineated species-specific habitat areas (species habitats) for all MESA-listed species, plus a number of other species identified in the State Wildlife Action Plan for which species habitats were available. For MESA-listed species alone, there were up to 25 species overlapping at any one place, although such concentrated hotspots were very rare. After consideration of the results, sites where there were five or more overlapping MESA-listed species were chosen as the threshold for inclusion as nuclei for Key Sites.

Tier 1 species and natural communities

To advance conservation planning, NHESP biologists prioritized among rare species and natural communities based on a combination of global rarity, state rarity, and the contribution Massachusetts occurrences make to overall global and regional (New England) conservation of the species or community. For example, New England Boneset is not only globally rare, but Massachusetts supports the entire known global population of this species. Thirty-seven species and 26 natural communities were determined to be of the highest priority, or Tier 1, for future conservation efforts (see the tables below).

The best occurrences (based on habitat quality and extent, population information, etc.) of these Tier 1 species and natural communities, and, for some elements, all of the occurrences, were included as nuclei for Key Sites to help ensure adequate protection and management of these highest-priority elements of biodiversity. Note that in many cases, some of these Tier 1 occurrences were already represented within the MESA-listed species hotspots described above.

Table 4-34: Tier 1 Species

Scientific Name	Common Name	MESA Status
Agalinis acuta	Sandplain Gerardia	E
Alasmidonta heterodon	Dwarf Wedgemussel	E
Callophrys hesseli	Hessel's Hairstreak	SC
Catocala pretiosa pretiosa	Precious Underwing	E
Charadrius melodus	Piping Plover	T
Chenopodium foggii	Fogg's Goosefoot	E
Cicindela dorsalis dorsalis	Northeastern Beach Tiger Beetle	E
Cicindela marginipennis	Cobblestone Tiger Beetle	E
Cicindela puritana	Puritan Tiger Beetle	E
Cicindela rufiventris hentzii	Hentz's Red-bellied Tiger Beetle	T
Coreopsis rosea	Pink Tickseed	--
Crataegus bicknellii	Bicknell's Hawthorn	E
Crotalus horridus	Timber Rattlesnake	E
Eleocharis diandra	Wright's Spike-rush	E
Emydoidea blandingii	Blanding's Turtle	T
Erynnis persius persius	Persius Duskywing	E
Eupatorium novae-angliae	New England Boneset	E
Glyptemys muhlenbergii	Bog Turtle	E
Heterocampa varia	Sandplain Heterocampa	T
Lampsilis cariosa	Yellow Lampmussel	E
Malaclemys terrapin	Northern Diamond-backed Terrapin	T
Malaxis bayardii	Bayard's Adder's Mouth	E
Metarranthis apiciaria	Barrens Metarranthis	E
Nicrophorus americanus	American Burying Beetle	E
Papaipema sulphurata	Water-willow Borer	T
Persicaria puritanorum	Pondshore Smartweed	SC
Poa saltuensis ssp. *languida*	Drooping Speargrass	E
Polygonum glaucum	Sea-beach Knotweed	SC
Potamogeton ogdenii	Ogden's Pondweed	E
Pseudemys rubriventris	Northern Red-bellied Cooter	E
Sabatia kennedyana	Plymouth Gentian	SC
Sagittaria teres	Terete Arrowhead	SC
Scirpus longii	Long's Bulrush	T
Sylvilagus transitionalis	New England Cottontail	--
Somatochlora georgiana	Coppery Emerald	E
Stenoporpia polygrammaria	Faded Gray	T
Sterna dougallii	Roseate Tern	E

Abbreviations: E – Endangered, T – Threatened, SC – Special Concern

Table 4-35: Tier 1 Natural Communities

Natural Community	State Rank
Black Ash-Red Maple-Tamarack Calcareous Seepage Swamp	S2
Black Gum-Pin Oak-Swamp White Oak "Perched" Swamp	S1
Brackish Tidal Marsh	S2
Calcareous Basin Fen	S1
Calcareous Forest Seep Community	S2
Calcareous Seepage Marsh	S2
Calcareous Sloping Fen	S2
Coastal Interdunal Marsh/Swale	S1
Coastal Plain Pondshore	S3
Coastal Salt Pond	S2
Coastal Salt Pond Marsh	S2
Estuarine Intertidal: Fresh/Brackish Flats	S2
Freshwater Tidal Marsh	S1
High-Terrace Floodplain Forest	S2
Major-River Floodplain Forest	S2
Maritime Dune Community	S2
Maritime Erosional Cliff Community	S2
Maritime Juniper Woodland/Shrubland	S2
Maritime Oak-Holly Forest/Woodland	S2
Maritime Pitch Pine on Dunes	S1
Pitch Pine-Scrub Oak Community	S2
Ridgetop Pitch Pine-Scrub Oak	S2
Sandplain Grassland	S1
Sandplain Heathland	S1
Scrub Oak Shrubland	S1
Sea-Level Fen	S1

State Rank: State ranks range from S1 (rare) to S5 (common). S1 communities typically have 5 or fewer occurrences, or very few remaining acres or miles of stream in Massachusetts, or are especially vulnerable to extirpation for other reasons. S2 communities typically have 6 to 20 occurrences, or few remaining acres or miles of stream in Massachusetts, or are very vulnerable to extirpation for other reasons. S3 communities typically have 21 to 100 occurrences, or limited acreage or miles of stream in Massachusetts. S4 communities are apparently secure in Massachusetts. S5 communities are demonstrably secure in Massachusetts.

Multiple, co-occurring, landscape-level resources

The first two criteria for Key Sites emphasize species and natural communities, sometimes described as fine-filter resources. In order to ensure inclusion of larger scale landscapes with relatively low levels of anthropogenic influence (e.g., low road density) and high ecosystem integrity, we identified *BioMap2* Forest Cores with the greatest number (six) of co-occurring coarse-filter landscape-level *BioMap2* resources (e.g., Vernal Pool Cores, Landscape Blocks, Wetland Cores, etc.) as nuclei in Key Sites. In a few ecoregions, none of the Forest Cores had six types of other *BioMap2* resources. In those ecoregions, the Forest Cores with five types of *BioMap2* resources and the highest individual number and/or acreage of such resources were chosen. Note that many of the sites identified as hotspots or Tier 1 species habitats also contain landscape-level *BioMap2* resources.

Construction of Key Sites

The Key Sites nuclei chosen via the three main criteria were then extended to complete the final Key Sites, as follows:

- Multiple rare species occurrences. Starting with each 5-species-or-more hotspot, the contiguous species-specific habitat areas for the MESA-listed species in the hotspot were chosen and merged with the hotspot itself.
- Tier 1 species and natural communities. Where NHESP biologists had delineated an additional buffering area for regulatory purposes (for example, the upland area adjacent to an aquatic

MESA-listed species), this buffer was added to the Tier 1 Key Site nuclei. No buffers were added to natural communities.

- Multiple, co-occurring, landscape-level resources. Each Forest Core was extended out with adjacent Landscape Block to the nearest roads.

Note that these extensions do <u>not</u> necessarily include all of the land that must be protected or managed to conserve the targeted resources in a Key Site. However, the Key Sites do include the <u>most important and highest priority</u> areas necessary for conservation of Key Site resources.

Finally, all of these Key Site nuclei and their extensions were compiled, merged, and then split into 122 individual Key Sites. Thus, a Key Site could have all three main components – multiple rare species, Tier 1 species or communities, and a highly diverse Forest Core – or it could have only one or two of these components. The Key Sites vary widely in size; the smallest is a cemetery at just over a third of an acre, the largest is the Outer Cape at over 47,000 acres. (See the map of Key Sites, Figure 4-42 below). Together, the Key Sites cover 553,390.9 acres, or 10.2% of the 5,430,428 acres in the *BioMap2* study area. **Just under 50% of the Key Sites acreage is already permanently protected.** Of the remaining acreage, about 8.3% is open water (which is inconsistently displayed as protected or not in the MassGIS Open Space layer) and about 8.6% is already developed (the undeveloped portions of small residential lots, active cemeteries, roads, etc.). This leaves about 183,879 acres, or 33.2% of the total Key Sites acreage, as unprotected, undeveloped, non-open-water uplands and wetlands.

Key Sites are already being used by the DCR and the DFG to inform and guide land protection statewide. In addition, the DFW, within DFG, is using Key Sites information to prioritize substantial, current habitat restoration and management on its Wildlife Management Areas. For more information on this effort, see the website here: http://www.mass.gov/eea/agencies/dfg/dfw/wildlife-habitat-conservation/key-sites-protecting-our-investment-in-public-land.html.

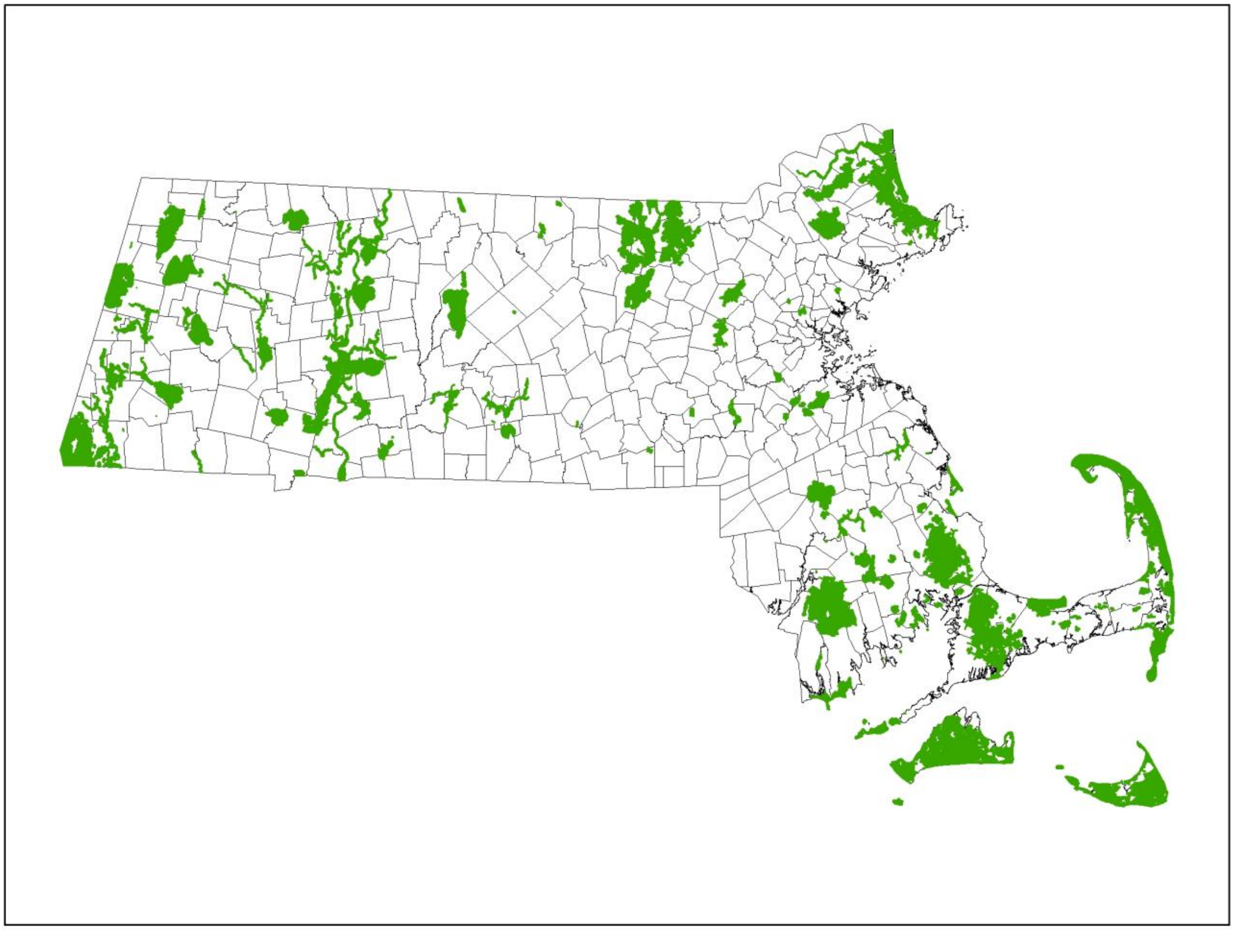


Figure 4-42: Key Sites.

Data from NHESP.