Chapter Three: Components of Core Habitat -

Section A: Species of Conservation Concern

BioMap2 includes areas delineated to capture the habitats specifically required for the long-term survival of 448 species of conservation concern. This group of species includes those listed under the Massachusetts Endangered Species Act (MESA; M.G.L. c131A) as well as additional species included in the Massachusetts State Wildlife Action Plan (SWAP), and they include vertebrate, invertebrate, and plant species. These species represent specific elements of the native biodiversity of Massachusetts that might not otherwise be captured through more coarse-filter conservation efforts. Except for tern foraging habitat and the broad habitats of the generalist Eastern Box Turtle, these species-specific habitat areas are included as Core Habitats within *BioMap2*. Tern foraging habitat (which includes extensive areas, mainly marine and salt marsh) and some Eastern Box Turtle habitat (based on the largest, highest quality habitat areas currently occupied by the Eastern Box Turtle) were included in Critical Natural Landscape.

MESA-listed Species

Mapping
Species listed under the MESA are some of the most imperiled species in the state, as evidenced by their rarity, population trends, and vulnerability to outside threats. Beginning in 2004, for species listed as Endangered, Threatened, or Special Concern pursuant to MESA, biologists at NHESP with species-specific expertise delineated species-specific habitat areas based on records of observations of those species that are currently in the NHESP database (see Appendix I, Rare Species Observation Forms). These records were evaluated against several criteria for inclusion into the database, such as the expertise of the observer, the documentation provided to confirm identification (photos, description, specimens, etc.), appropriateness of habitat and time of year, whether it was observed within the known range for the species, etc. The NHESP staff developed and implemented mapping guidelines unique to each species, based on a review of the literature, data in the NHESP database, ongoing research, and expert knowledge. These mapping guidelines were developed to include all aspects of a species' life cycle that is spent within the state, and to include all habitats necessary for the long-term survival of each local population (see Appendix J, Mapping Guidelines Outline). For example, the mapping guidelines for a turtle species would include guidelines for delineating overwintering, foraging, and nesting habitat, as well as corridors connecting all these habitat types. A variety of GIS data layers, such as aerial photographs, DEP wetlands, DOT roads, land use, and surficial geology, as well as information in the individual observations records themselves, were used to delineate the habitats of these species. The maximum distance mapped from an individual observation is based on a conservative estimate—again, based on the latest scientific information—of the distance an individual of that species is likely to travel. Features that may act as barriers to movement, whether they are manmade highways or areas of open water, are also included as limiting factors in the guidelines. Developed areas or areas that do not provide high-quality habitat for the species were removed from mapped habitat areas. Only records that meet the strict data

acceptance criteria of NHESP were used in this delineation (see Appendix K, Data Acceptance Guidelines), and only those records of observations between 1985 and 2010 were used.

The areas delineated as habitat for MESA-listed species are used by NHESP staff for many conservation purposes, including land protection prioritization, regulation, habitat restoration, and definition of survey areas. These mapped areas are updated as new information is received (such as additional observation records, the results of new research, new spatial data including new aerials or land use layers, etc.). In that way, NHESP is always using the latest information available for conservation, restoration, regulation, and research. The species-specific habitat polygons used in *BioMap2* were extracted from the NHESP database on August 12, 2010, and are based on records documenting nearly 5,000 current populations of state-listed species reported to NHESP.

NHESP staff involved in mapping species habitat include:

- Plants: Bryan Connolly, Jennifer Garrett
- Invertebrates: Marea Gabriel, Lynn Harper, Kim Justham, Michael Nelson, Tim Simmons
- Vertebrates: Kristin Black, Chris Buelow, Lori Erb, Jacob Kubel, Lisa MacGillivray, Misty-Anne Marold, Scott Melvin, Carolyn Mostello
- GIS Staff: Tara Boswell
- Data Staff: Tara Huguenin, Kim Justham, Sarah Maier

Although the NHESP currently (2010) lists 435 species under the MESA, only habitats for 413 of these species were included in *BioMap2*. This is true for three reasons:

- A number of species are strictly marine in Massachusetts (whales, sea turtles).
- Others require such ephemeral terrestrial habitats that are so fleeting on the landscape that it would be impossible to delineate meaningful habitat for them that would persist and be occupied for any length of time (Golden-winged Warbler).
- Several species are currently included on the MESA List, but have not been seen in Massachusetts in more than 25 years.

Because *BioMap2* is intended to represent areas that will support the long-term persistence of the native biodiversity of Massachusetts, some poor quality habitats for MESA-listed species were not included. NHESP staff followed standard Natural Heritage Element Occurrence Ranking Methodology in order to evaluate the estimated viability (probability of persistence) of populations of a given species. This system is used to rank populations on their overall relative quality based on population size, abiotic and biotic conditions, and landscape context. Populations of listed species with poor probability of persistence for the long term (usually D-ranked occurrences) were not included in *BioMap2*.

Table 7. Natural Heritage Element Occurrence Rankings and their descriptions

Viability Rank	Estimated Viability	Descriptions
A	Excellent	If current conditions prevail, population is very likely to persist for the foreseeable future in its current condition or better
B	Good	If current conditions prevail, population is likely to persist for the foreseeable future in its current condition or better
C	Fair	Population persistence is uncertain under current conditions but may persist for the foreseeable future with appropriate protection or management
D	Poor	Population has a high risk of extirpation

Additionally, for two Special Concern species of turtle—the Eastern Box Turtle and the Wood Turtle—only the very highest quality sites are included in *BioMap2*. This is because they require such large areas of habitat for long-term persistence, and because they are still fairly well represented on the landscape, as indicated by their listing as Species of Special Concern, the lowest category of vulnerability under the MESA. Because the Eastern Box Turtle is a wide-ranging generalist species, the large landscape needed by this species was included in Critical Natural Landscape and only the very site-specific high priority sites (nesting areas, areas of high turtle density, etc.) are included in Core Habitat.

Also included in Critical Natural Landscape rather than Core Habitat is the foraging habitat for four species of tern. The MESA lists three species of tern (Arctic, Common, and Least) as Species of Special Concern and one species (Roseate) as Endangered. These species nest on beaches, islands, and in salt marshes along the Massachusetts coast, foraging over the open ocean, in bays and inlets, and in salt marshes. Because of the wide-ranging habitat of these species when they forage, and the fact that most of it is open ocean, tern foraging habitat was included in *BioMap2* as Critical Natural Landscape, while breeding and staging areas are included in Core Habitat.

Vertebrate Species

Fish

There are 10 species of fish listed under the Massachusetts Endangered Species Act; habitats for all of these species are included in *BioMap2*. Freshwater habitat for these species is delineated based on current observation records, and generally includes aquatic habitats (rivers, streams, lakes, and ponds depending on the species) that are within 2 kilometers of a current observation record. Dams without fish ladders were considered barriers to movements of these species, and therefore are limiting factors in habitat delineation. Depending on the species, changes to the flow rates (such as impoundments for riverine species, changes in stream class size such as where tributaries join main stems, etc.) can also limit the extent of habitat delineated. Habitats included in the fish species' "footprint" include those used during different seasons of the year and different portions of the animals' lives such as breeding habitat, spawning habitat, juvenile habitat, foraging habitat, and migration routes where applicable.

Table 8. MESA-listed fish species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Shortnose Sturgeon	*Acipenser brevirostrum*	E	Mapped
Atlantic Sturgeon	*Acipenser oxyrinchus*	E	Mapped
Longnose Sucker	*Catostomus catostomus*	SC	Mapped
Lake Chub	*Couesius plumbeus*	E	Mapped
Threespine Stickleback	*Gasterosteus aculeatus*	T	Mapped
Eastern Silvery Minnow	*Hybognathus regius*	SC	Mapped
American Brook Lamprey	*Lampetra appendix*	T	Mapped
Burbot	*Lota lota*	SC	Mapped
Bridle Shiner	*Notropis bifrenatus*	SC	Mapped
Northern Redbelly Dace	*Phoxinus eos*	E	Mapped

Amphibians

There are four species of amphibians listed in Massachusetts under MESA—three salamanders and one toad. Habitats for all of these species are included in *BioMap2*. Habitat delineations for these species incorporate the ephemeral breeding/larval habitats as well as the upland habitats used by the terrestrial metamorphs and adults for the bulk of their lives, and enough contiguous habitat between breeding pools and terrestrial habitats to allow for successful movements between them. For the Ambystomid salamanders, the upland habitat is primarily forested areas within 2,000 feet of a current observation record. For the Spadefoot toad, the preferred upland habitat includes much more open areas with scattered bushes and loose sandy soils. Roads with moderate to heavy traffic are considered to be barriers to movement for all of these species, and therefore limit the extent of habitat delineated within populated areas.

Table 9. MESA-listed amphibian species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Jefferson Salamander	*Ambystoma jeffersonianum*	SC	Mapped
Blue-spotted Salamander	*Ambystoma laterale*	SC	Mapped
Marbled Salamander	*Ambystoma opacum*	T	Mapped
Eastern Spadefoot	*Scaphiopus holbrookii*	T	Mapped

Reptiles

There are 15 reptile species on the MESA list, including five sea turtle species, six non-marine turtle species, and four species of snake. Because *BioMap2* is not intended to be a marine conservation plan and because they do not nest in Massachusetts, no habitats are included for the sea turtles listed as imperiled in Massachusetts. Habitat for the Diamond-backed Terrapin, a brackish-water species, is included in *BioMap2* because the life cycle of this resident species is primarily played out within the 0.3 nautical miles of the shore of Massachusetts that is included in *BioMap2*. Habitats for all MESA-listed non-marine turtle and snake species are included in *BioMap2*. Areas incorporated into the conservation plan include overwintering habitat (such as hibernacula for snakes, large ponds for the Northern Red-bellied Cooter, forested areas with loose soils for Eastern Box Turtles), foraging habitat, breeding and nesting habitat, and migration corridors between these different areas.

Because the Wood Turtle and Eastern Box Turtle require such large habitat areas within Massachusetts, only the largest, highest quality, occupied habitat areas for them are included in *BioMap2*.

- Eastern Box Turtle
  The most critical habitats, such as nest sites and areas with the highest densities of Eastern Box Turtles within the broader landscape, were included within Core Habitat. The larger landscape blocks required for this species were included in Critical Natural Landscape rather than Core Habitat, because the Eastern Box Turtle is a habitat generalist which needs large intact areas for long-term persistence in Massachusetts. These large habitat areas are based on Eastern Box Turtle home range information from various research studies as well as population viability models, and are usually larger than 500 acres each, balanced across four conservation management regions (loosely based on ecoregions, but more broadly defined to include only the areas within which the Eastern Box Turtle is found in Massachusetts, and separated by barriers to Eastern Box Turtle movements, such as the Cape Cod Canal). Observation records more than 25 years old could be considered in the delineation of these large landscape areas where there is every reason to believe the habitat is still suitable and populations still exist, particularly since individuals of this species can live for many decades, sometimes as long as 100 years. Some of these Eastern Box Turtle landscapes exist in areas where the Landscape Blocks were delineated through computer modeling, so there can be overlap of Eastern Box Turtle landscape areas and Landscape Blocks defined by the IEI modeling.
- Wood Turtle
  The best populations of this species were included in *BioMap2* as Species of Conservation Concern Core Habitat.

Table 10. MESA-listed reptile species, as of 2010.

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Copperhead	*Agkistrodon contortrix*	E	Mapped
Loggerhead Seaturtle	*Caretta caretta*	T	Not Mapped
Eastern Worm Snake	*Carphophis amoenus*	T	Mapped
Green Seaturtle	*Chelonia mydas*	T	Not Mapped
Timber Rattlesnake	*Crotalus horridus*	E	Mapped
Leatherback Seaturtle	*Dermochelys coriacea*	E	Not mapped
Blanding's Turtle	*Emydoidea blandingii*	T	Mapped
Hawksbill Seaturtle	*Eretmochelys imbricate*	E	Not Mapped
Wood Turtle	*Glyptemys insculpta*	SC	Mapped
Bog Turtle	*Glyptemys muhlenbergii*	E	Mapped
Kemp’s Ridley Seaturtle	*Lepidochelys kempii*	E	Not Mapped
Diamond-backed Terrapin	*Malaclemys terrapin*	T	Mapped
Eastern Rat Snake	*Pantherophis alleghaniensis*	E	Mapped
Northern Red-bellied Cooter	*Pseudemys rubriventris* pop. 1	E	Mapped
Eastern Box Turtle	*Terrapene carolina*	SC	Mapped

Birds

The Massachusetts Endangered Species List includes 28 bird species, and *BioMap2* contains habitat areas delineated for all but one of those species. Because of the ephemeral and unstable nature of the habitat needed by the Golden-winged Warbler, no habitat areas were included in *BioMap2* for this species. For birds, because so many species may use Massachusetts as a stopover area in their annual movements, and because conservation efforts are most effective for listed species by focusing on breeding areas, only observation reports of breeding occurrences are mapped by NHESP staff. There were two exceptions. One exception is the four species of tern that breed in Massachusetts. Staging areas which include large congregations of terns gathering to migrate south for the winter are also delineated by NHESP staff for conservation purposes and are included in *BioMap2*. Habitat types delineated for tern species and included in *BioMap2* are breeding habitats, nesting habitats, foraging habitat used by adults and young, and staging areas. The foraging areas delineated for the four tern species are included in Critical Natural Landscape rather than Core Habitat, because they are so broad and include primarily open ocean, inlets, bays, and salt marshes. These brackish and marine landscape areas are based on actual data collected on terns observed foraging in Nantucket Sound and Buzzard's Bay, but also on estimates of foraging habits of birds nesting or staging in particular parts of the state. High density colonies would require individuals to travel further to forage, so foraging areas could contain habitat out to 1 or 8 miles from shore, depending on the species and the density of birds utilizing a particular site. The other exception is significant wintering areas of Bald Eagle; these were also included in *BioMap2*.

Table 11. MESA-listed bird species, as of 2010.

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Sharp-shinned Hawk	*Accipiter striatus*	SC	Mapped
Henslow's Sparrow	*Ammodramus henslowii*	E	Mapped
Grasshopper Sparrow	*Ammodramus savannarum*	T	Mapped
Short-eared Owl	*Asio flammeus*	E	Mapped
Long-eared Owl	*Asio otus*	SC	Mapped
Upland Sandpiper	*Bartramia longicauda*	E	Mapped
American Bittern	*Botaurus lentiginosus*	E	Mapped
Piping Plover	*Charadrius melodus*	T	Mapped
Northern Harrier	*Circus cyaneus*	T	Mapped
Sedge Wren	*Cistothorus platensis*	E	Mapped
Blackpoll Warbler	*Dendroica striata*	SC	Mapped
Peregrine Falcon	*Falco peregrinus*	E	Mapped
Common Moorhen	*Gallinula chloropus*	SC	Mapped
Common Loon	*Gavia immer*	SC	Mapped
Bald Eagle	*Haliaeetus leucocephalus*	E	Mapped
Least Bittern	*Ixobrychus exilis*	E	Mapped
Leach's Storm-petrel	*Oceanodroma leucorhoa*	E	Mapped
Mourning Warbler	*Oporornis philadelphia*	SC	Mapped
Northern Parula	*Parula americana*	T	Mapped
Pied-billed Grebe	*Podilymbus podiceps*	E	Mapped
Vesper Sparrow	*Pooecetes gramineus*	T	Mapped
King Rail	*Rallus elegans*	T	Mapped
Roseate Tern	*Sterna dougallii*	E	Mapped
Common Tern	*Sterna hirundo*	SC	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Arctic Tern	*Sterna paradisaea*	SC	Mapped
Least Tern	*Sternula antillarum*	SC	Mapped
Barn Owl	*Tyto alba*	SC	Mapped
Golden-winged Warbler	*Vermivora chrysoptera*	E	Not Mapped

Mammals

Eleven species of mammal are listed under the Massachusetts Endangered Species Act, but only habitats for four of these species have been delineated and included in *BioMap2*. Six of the species not included in *BioMap2* are whales, which are marine and therefore not included in this conservation plan, and the seventh species is the Indiana Myotis—a federally Endangered bat species that has not been seen in Massachusetts since the 1930s. The four MESA-listed mammal species included in *BioMap2* are all small animals with very limited habitats, and the areas delineated for their conservation include areas that provide all the necessary elements needed for their survival such as foraging habitat, breeding and nesting habitat, and overwintering habitat.

Table 12. MESA-listed mammal species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Sei Whale	*Balaenoptera borealis*	E	Not Mapped
Blue Whale	*Balaenoptera musculus*	E	Not Mapped
Fin Whale	*Balaenoptera physalus*	E	Not Mapped
Northern Right Whale	*Eubalaena glacialis*	E	Not Mapped
Humpback Whale	*Megaptera novaeangliae*	E	Not Mapped
Small-footed Myotis	*Myotis leibii*	SC	Mapped
Indiana Myotis	*Myotis sodalus*	E	Not Mapped
Sperm Whale	*Physeter catodon*	E	Not Mapped
Rock Shrew	*Sorex dispar*	SC	Mapped
Water Shrew	*Sorex palustris*	SC	Mapped
Southern Bog Lemming	*Synaptomys cooperi*	SC	Mapped

Invertebrate Species

Freshwater Mussels

There are seven species of freshwater mussel listed under the Massachusetts Endangered Species Act; habitats for all of these species are included in *BioMap2*. Delineation of habitat for these species incorporates areas for juvenile and adult mussels by including areas with appropriate substrate, water flows, and habitat connectivity, as well as considering larval host fish dispersal. Dams and other barriers limit the extent of the areas mapped for MESA-listed mussel species, and a riverine population's delineated habitat extends no more than 2 to 5 kilometers, depending on intervening habitat conditions, from a current observation record in any given area. Habitat for lake and pond populations includes the entire water body unless dispersal between observation records is obstructed.

Table 13. MESA-listed freshwater mussel species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Dwarf Wedgemussel	*Alasmidonta heterodon*	E	Mapped
Triangle Floater	*Alasmidonta undulata*	SC	Mapped
Brook Floater	*Alasmidonta varicosa*	E	Mapped
Yellow Lampmussel	*Lampsilis cariosa*	E	Mapped
Tidewater Mucket	*Leptodea ochracea*	SC	Mapped
Eastern Pondmussel	*Ligumia nasuta*	SC	Mapped
Creeper	*Strophitus undulatus*	SC	Mapped

Dragonflies and Damselflies

Twenty-five species of dragonfly (insects in the order Odonata and suborder Anisoptera) and five species of damselfly (insects in the order Odonata and suborder Zygoptera) are on the MESA list, and critical habitats for all of them are mapped and included in *BioMap2*. Species-specific habitats for odonates are focused around the aquatic larval habitats (rivers, streams, bogs, coastal plain ponds, and other wetlands) as well as upland habitat for adults to sexually mature, feed, roost, and breed. The necessary adult foraging and upland habitat includes a wide variety of habitat types depending on the species in question, and may contain open fields, forests, wetlands, streams, agricultural areas, and shrublands. Because habitat needs and adult foraging distances are poorly known for a number of odonate species, upland habitat areas are conservatively delineated and are primarily limited to within 100 m from the aquatic larval habitat. Heavily developed sites, including residential areas which may provide some foraging habitat in backyards, are excluded from areas mapped for MESA-listed odonates as they are not ideal long-term conservation targets.

Table 14. MESA-listed dragonfly and damselfly species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Subarctic Darner	*Aeshna subarctica*	T	Mapped
Comet Darner	*Anax longipes*	SC	Mapped
Ocellated Darner	*Boyeria grafiana*	SC	Mapped
Tule Bluet	*Enallagma carunculatum*	SC	Mapped
Attenuated Bluet	*Enallagma daeckii*	SC	Mapped
New England Bluet	*Enallagma laterale*	SC	Mapped
Scarlet Bluet	*Enallagma pictum*	T	Mapped
Pine Barrens Bluet	*Enallagma recurvatum*	T	Mapped
Spine-crowned Clubtail	*Gomphus abbreviatus*	E	Mapped
Harpoon Clubtail	*Gomphus descriptus*	E	Mapped
Midland Clubtail	*Gomphus fraternus*	E	Mapped
Rapids Clubtail	*Gomphus quadricolor*	T	Mapped
Cobra Clubtail	*Gomphus vastus*	SC	Mapped
Skillet Clubtail	*Gomphus ventricosus*	SC	Mapped
Umber Shadowdragon	*Neurocordulia obsoleta*	SC	Mapped
Stygian Shadowdragon	*Neurocordulia yamaskanensis*	SC	Mapped
Brook Snaketail	*Ophiogomphus aspersus*	SC	Mapped
Riffle Snaketail	*Ophiogomphus carolus*	T	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Spatterdock Darner	*Rhionaeschna mutata*	SC	Mapped
Ski-tipped Emerald	*Somatochlora elongata*	SC	Mapped
Forcipate Emerald	*Somatochlora forcipata*	SC	Mapped
Coppery Emerald	*Somatochlora georgiana*	E	Mapped
Incurvate Emerald	*Somatochlora incurvata*	T	Mapped
Kennedy's Emerald	*Somatochlora kennedyi*	E	Mapped
Mocha Emerald	*Somatochlora linearis*	SC	Mapped
Riverine Clubtail	*Stylurus amnicola*	E	Mapped
Zebra Clubtail	*Stylurus scudderi*	SC	Mapped
Arrow Clubtail	*Stylurus spiniceps*	T	Mapped
Ebony Boghaunter	*Williamsonia fletcheri*	E	Mapped
Ringed Boghaunter	*Williamsonia lintneri*	E	Mapped

Beetles

Eight of the nine beetle species listed under the Massachusetts Endangered Species Act are tiger beetles (*Cicindela* spp.). The ninth species is the American Burying Beetle—a federally Endangered species that is currently supported through a supplementation program in a small area in Massachusetts—and due to its fossorial habits and the difficulty in identifying critical supporting habitat, it is not included in *BioMap2*. Tiger beetle habitat, on the other hand, is fairly specific although dynamic over time, so habitats are delineated for the eight remaining MESA-listed beetle species. As larvae, tiger beetles live in burrows underground and require species specific substrates for those burrows, all of which are fairly void of vegetation regardless of beetle species. Substrates that support tiger beetle populations may be sandy beaches, rocky outcrops, stream banks, or simple paths through shrublands depending on the species. Appropriate habitat patches are delineated based on the current observation records contained in the NHESP database, and include enough of the local habitat to allow for movements of the local populations as the dynamic substrates on which they depend change from year to year.

Table 15. MESA-listed beetle species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Northeastern Beach Tiger Beetle	*Cicindela dorsalis dorsalis*	E	Mapped
Twelve-spotted Tiger Beetle	*Cicindela duodecimguttata*	SC	Mapped
Bank Tiger Beetle	*Cicindela limbalis*	SC	Mapped
Cobblestone Tiger Beetle	*Cicindela marginipennis*	E	Mapped
Barrens Tiger Beetle	*Cicindela patruela*	E	Mapped
Puritan Tiger Beetle	*Cicindela puritana*	E	Mapped
Purple Tiger Beetle	*Cicindela purpurea*	SC	Mapped
Hentz's Redbelly Tiger Beetle	*Cicindela rufiventris hentzii*	T	Mapped
American Burying Beetle	*Nicrophorus americanus*	E	Not Mapped

Butterflies and Moths

Forty-five MESA-listed moth and butterfly species are mapped based on the extent of breeding habitat. For each species, breeding habitat is defined as a vegetation community of particular composition and structure. Presence of larval host plants is a critical compositional factor.

Where the breeding habitat is fairly widespread, mapped habitat is limited to that occurring within 1 or 2 kilometers (depending on the species) from an observation record. Heavily developed areas are excluded from delineated habitat. The Straight Lined Mallow Moth (*Bagisara rectifascia*) was once thought to be limited in its food source, habitat, and range in the state, but recent survey efforts have demonstrated that this species is more widespread and its habitat requirements less limiting than previously thought. Therefore, it is proposed for de-listing as a Species of Special Concern in Massachusetts, and is not included in *BioMap2*.

Table 16. MESA-listed butterfly and moth species, as of 2010.

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Coastal Heathland Cutworm	*Abagrotis nefascia*	SC	Mapped
Barrens Daggermoth	*Acronicta albarufa*	T	Mapped
Drunk Apamea Moth	*Apamea inebriata*	SC	Mapped
New Jersey Tea Inchworm	*Apodrepanulatrix liberaria*	E	Mapped
Straight Lined Mallow Moth	*Bagisara rectifascia*	SC	Not Mapped
Hessel's Hairstreak	*Callophrys hesseli*	SC	Mapped
Frosted Elfin	*Callophrys irus*	SC	Mapped
Bog Elfin	*Callophrys lanoraieensis*	T	Mapped
Gerhard's Underwing Moth	*Catocala herodias gerhardi*	SC	Mapped
Precious Underwing Moth	*Catocala pretiosa pretiosa*	E	Mapped
Waxed Sallow Moth	*Chaetaglaea cerata*	SC	Mapped
Melsheimer's Sack Bearer	*Cicinnus melsheimeri*	T	Mapped
Chain Dot Geometer	*Cingilia catenaria*	SC	Mapped
Unexpected Cycnia	*Cycnia inopinatus*	T	Mapped
Three-lined Angle Moth	*Digrammia eremiata*	T	Mapped
Imperial Moth	*Eacles imperialis*	T	Mapped
Early Hairstreak	*Erora laeta*	T	Mapped
Persius Duskywing	*Erynnis persius persius*	E	Mapped
Sandplain Euchlaena	*Euchlaena madusaria*	SC	Mapped
Dion Skipper	*Euphyes dion*	T	Mapped
The Pink Streak	*Faronta rubripennis*	T	Mapped
Phyllira Tiger Moth	*Grammia phyllira*	E	Mapped
Slender Clearwing Sphinx Moth	*Hemaris gracilis*	SC	Mapped
Barrens Buckmoth	*Hemileuca maia*	SC	Mapped
Buchholz's Gray	*Hypomecis buchholzaria*	E	Mapped
Pine Barrens Itame	*Itame* sp. 1 nr. *inextricata*	SC	Mapped
Pale Green Pinion Moth	*Lithophane viridipallens*	SC	Mapped
Twilight Moth	*Lycia rachelae*	E	Mapped
Pine Barrens Lycia	*Lycia ypsilon*	T	Mapped
Barrens Metarranthis Moth	*Metarranthis apiciaria*	E	Mapped
Coastal Swamp Metarranthis Moth	*Metarranthis pilosaria*	SC	Mapped
Northern Brocade Moth	*Neoligia semicana*	SC	Mapped
Dune Noctuid Moth	*Oncocnemis riparia*	SC	Mapped
Pitcher Plant Borer Moth	*Papaipema appassionata*	T	Mapped
Ostrich Fern Borer Moth	*Papaipema* sp. 2 nr. *pterisii*	SC	Mapped
Chain Fern Borer Moth	*Papaipema stenocelis*	T	Mapped
Water-willow Stem Borer	*Papaipema sulphurata*	T	Mapped
Mustard White	*Pieris oleracea*	T	Mapped
Pink Sallow	*Psectraglaea carnosa*	SC	Mapped
Southern Ptichodis	*Ptichodis bistrigata*	T	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Orange Sallow Moth	*Rhodoecia aurantiago*	T	Mapped
Oak Hairstreak	*Satyrium favonius*	SC	Mapped
Spartina Borer Moth	*Spartiniphaga inops*	SC	Mapped
Faded Gray Geometer	*Stenoporpia polygrammaria*	T	Mapped
Pine Barrens Zale	*Zale* sp. 1 nr. *lunifera*	SC	Mapped
Pine Barrens Zanclognatha	*Zanclognatha martha*	T	Mapped

Miscellaneous Invertebrates

There are an additional 16 species of invertebrate that are not insects or mussels but are listed under the Massachusetts Endangered Species Act. Of these, three species are not included in *BioMap2* because they have not been documented in the state within the last 25 years. The remaining 13 invertebrate species include crustaceans, snails, a sponge, and a flatworm. These species all have habitats that are fairly constrained and very limited in the landscape, and can be defined by the aquatic or wetland habitat in which they are found.

Table 17. MESA-listed miscellaneous invertebrate species, as of 2010.

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Intricate Fairy Shrimp	*Eubranchipus intricatus*	SC	Mapped
Agassiz's Clam Shrimp	*Eulimnadia agassizii*	E	Mapped
Walker's Limpet	*Ferrissia walkeri*	SC	Mapped
New England Siltsnail	*Floridobia winkleyi*	SC	Mapped
Northern Spring Amphipod	*Gammarus pseudolimnaeus*	SC	Mapped
American Clam Shrimp	*Limnadia lenticularis*	SC	Mapped
Coastal Marsh Snail	*Littoridinops tenuipes*	SC	Mapped
New England Medicinal Leech	*Macrobdella sestertia*	SC	Not Mapped
Boreal Marstonia	*Marstonia lustrica*	E	Mapped
Sunderland Spring Planarian	*Polycelis remota*	E	Mapped
Slender Walker	*Pomatiopsis lapidaria*	E	Mapped
Smooth Branched Sponge	*Spongilla aspinosa*	SC	Mapped
Taconic Cave Amphipod	*Stygobromus borealis*	E	Not Mapped
Piedmont Groundwater Amphipod	*Stygobromus tenuis tenuis*	SC	Mapped
Coastal Swamp Amphipod	*Synurella chamberlaini*	SC	Mapped
Boreal Turret Snail	*Valvata sincera*	E	Not Mapped

Plant Species

The Massachusetts Endangered Species Act lists 259 species of vascular plant as Endangered, Threatened, or Special Concern, as of 2010. Of these 259, only four species are not included in *BioMap2*, and they are excluded because none of these species has been seen within Massachusetts in the last 25 years. The habitats for the remaining 255 species are delineated based on the specific needs of each species—whether the limestone-rich dolomite ledges of western Massachusetts, or the seasonally variable coastal plain ponds of Cape Cod. The stable or ephemeral nature of each species is taken into account when reviewing the records and when mapping habitats, and soil types, seed dispersal and longevity, and site successional stage are incorporated into habitat mapping guidelines. Species-specific habitats are conservatively delineated based on observation records in the NHESP database.

Table 18. MESA-listed plant species, as of 2010.

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Black Maple	*Acer nigrum*	SC	Mapped
Black Cohosh	*Actaea racemosa*	E	Mapped
Climbing Fumitory	*Adlumia fungosa*	SC	Mapped
Sandplain Gerardia	*Agalinis acuta*	E	Mapped
Purple Giant Hyssop	*Agastache scrophulariifolia*	E	Mapped
Lesser Snakeroot	*Ageratina aromatica*	E	Mapped
Small-flowered Agrimony	*Agrimonia parviflora*	E	Mapped
Hairy Agrimony	*Agrimonia pubescens*	T	Mapped
Mountain Alder	*Alnus viridis* ssp. *crispa*	T	Mapped
Bartram's Shadbush	*Amelanchier bartramiana*	T	Mapped
Nantucket Shadbush	*Amelanchier nantucketensis*	SC	Mapped
Roundleaf Shadbush	*Amelanchier sanguinea*	SC	Mapped
Annual Peanut-grass	*Amphicarpum amphicarpon*	E	Mapped
Putty-root	*Aplectrum hyemale*	E	Mapped
Lyre-leaved Rock-cress	*Arabidopsis lyrata*	E	Mapped
Dwarf Mistletoe	*Arceuthobium pusillum*	SC	Mapped
Arethusa	*Arethusa bulbosa*	T	Mapped
Green Dragon	*Arisaema dracontium*	T	Mapped
Purple Needlegrass	*Aristida purpurascens*	T	Mapped
Seabeach Needlegrass	*Aristida tuberculosa*	T	Mapped
Purple Milkweed	*Asclepias purpurascens*	E	Mapped
Linear-leaved Milkweed	*Asclepias verticillata*	T	Mapped
Mountain Spleenwort	*Asplenium montanum*	E	Mapped
Wall-rue Spleenwort	*Asplenium ruta-muraria*	T	Mapped
Swamp Birch	*Betula pumila*	E	Mapped
Eaton's Beggar-ticks	*Bidens eatonii*	E	Mapped
Estuary Beggar-ticks	*Bidens hyperborea*	E	Mapped
Downy Wood-mint	*Blephilia ciliata*	E	Mapped
Hairy Wood-mint	*Blephilia hirsuta*	E	Mapped
Smooth Rock-cress	*Boechera laevigata*	T	Mapped
Green Rock-cress	*Boechera missouriensis*	T	Mapped
River Bulrush	*Bolboschoenus fluviatilis*	SC	Mapped
Reed Bentgrass	*Calamagrostis pickeringii*	E	Mapped
New England Northern Reed Grass	*Calamagrostis stricta* ssp. *inexpansa*	E	Mapped
Low Bindweed	*Calystegia spithamaea*	E	Mapped
Purple Cress	*Cardamine douglassii*	E	Mapped
Long's Bitter-cress	*Cardamine longii*	E	Mapped
Fen Cuckoo Flower	*Cardamine pratensis* var. *palustris*	T	Mapped
Foxtail Sedge	*Carex alopecoidea*	T	Mapped
Back's Sedge	*Carex backii*	E	Mapped
Bailey's Sedge	*Carex baileyi*	T	Mapped
Bush's Sedge	*Carex bushii*	E	Mapped
Chestnut-colored Sedge	*Carex castanea*	E	Mapped
Creeping Sedge	*Carex chordorrhiza*	E	Mapped
Davis's Sedge	*Carex davisii*	E	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Handsome Sedge	*Carex formosa*	T	Mapped
Glaucescent Sedge	*Carex glaucodea*	E	Mapped
Slender Woodland Sedge	*Carex gracilescens*	E	Not Mapped
Gray's Sedge	*Carex grayi*	T	Mapped
Hitchcock's Sedge	*Carex hitchcockiana*	SC	Mapped
Shore Sedge	*Carex lenticularis*	T	Mapped
Glaucous Sedge	*Carex livida*	E	Not Mapped
False Hop-sedge	*Carex lupuliformis*	E	Mapped
Midland Sedge	*Carex mesochorea*	E	Mapped
Michaux's Sedge	*Carex michauxiana*	E	Mapped
Mitchell's Sedge	*Carex mitchelliana*	T	Mapped
Few-fruited Sedge	*Carex oligosperma*	E	Mapped
Few-flowered Sedge	*Carex pauciflora*	E	Mapped
Variable Sedge	*Carex polymorpha*	E	Mapped
Schweinitz's Sedge	*Carex schweinitzii*	E	Mapped
Dioecious Sedge	*Carex sterilis*	T	Mapped
Walter's Sedge	*Carex striata*	E	Mapped
Fen Sedge	*Carex tetanica*	SC	Mapped
Hairy-fruited Sedge	*Carex trichocarpa*	T	Mapped
Tuckerman's Sedge	*Carex tuckermanii*	E	Mapped
Cat-tail Sedge	*Carex typhina*	T	Mapped
Nodding Chickweed	*Cerastium nutans*	E	Mapped
Devil's-bit	*Chamaelirium luteum*	E	Mapped
Fogg's Goosefoot	*Chenopodium foggii*	E	Mapped
Narrow-leaved Spring Beauty	*Claytonia virginica*	E	Mapped
Purple Clematis	*Clematis occidentalis*	SC	Mapped
Hemlock Parsley	*Conioselinum chinense*	SC	Mapped
Autumn Coralroot	*Corallorhiza odontorhiza*	SC	Mapped
Broom Crowberry	*Corema conradii*	SC	Mapped
Bicknell's Hawthorn	*Crataegus bicknellii*	E	Mapped
Bushy Rockrose	*Crocanthemum dumosum*	SC	Mapped
Fragile Rock-brake	*Cryptogramma stelleri*	E	Mapped
Northern Wild Comfrey	*Cynoglossum virginianum* var. *boreale*	E	Mapped
Engelmann's Umbrella-sedge	*Cyperus engelmannii*	T	Mapped
Houghton's Flatsedge	*Cyperus houghtonii*	E	Mapped
Ram's-head Lady's-slipper	*Cypripedium arietinum*	E	Mapped
Small Yellow Lady's-slipper	*Cypripedium parviflorum* var. *makasin*	E	Mapped
Showy Lady's-slipper	*Cypripedium reginae*	SC	Mapped
Tufted Hairgrass	*Deschampsia cespitosa* ssp. *glauca*	E	Mapped
Large-bracted Tick-trefoil	*Desmodium cuspidatum*	T	Mapped
Mattamuskeet Panic-grass	*Dichanthelium dichotomum* ssp. *mattamuskeetense*	E	Mapped
Commons's Panic-grass	*Dichanthelium ovale* ssp. *pseudopubescens*	SC	Mapped
Rough Panic-grass	*Dichanthelium scabriusculum*	T	Mapped
Wright's Panic-grass	*Dichanthelium wrightianum*	SC	Mapped
Cornel-leaved Aster	*Doellingeria infirma*	E	Mapped
American Waterwort	*Elatine americana*	E	Mapped
Wright's Spike-rush	*Eleocharis diandra*	E	Mapped
Intermediate Spike-sedge	*Eleocharis intermedia*	T	Mapped
Tiny-fruited Spike-sedge	*Eleocharis microcarpa* var. *filiculmis*	E	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Ovate Spike-sedge	*Eleocharis ovata*	E	Mapped
Few-flowered Spike-sedge	*Eleocharis quinqueflora*	E	Mapped
Three-angled Spike-sedge	*Eleocharis tricostata*	E	Mapped
Hairy Wild Rye	*Elymus villosus*	E	Mapped
Dwarf Scouring-rush	*Equisetum scirpoides*	SC	Mapped
Frank's Lovegrass	*Eragrostis frankii*	SC	Mapped
Parker's Pipewort	*Eriocaulon parkeri*	E	Mapped
Slender Cottongrass	*Eriophorum gracile*	T	Mapped
New England Boneset	*Eupatorium novae-angliae*	E	Mapped
Northern Bedstraw	*Galium boreale*	E	Mapped
Labrador Bedstraw	*Galium labradoricum*	T	Mapped
Purple Cudweed	*Gamochaeta purpurea*	E	Mapped
Andrews' Bottle Gentian	*Gentiana andrewsii*	E	Mapped
Dwarf Rattlesnake-plantain	*Goodyera repens*	E	Mapped
Spurred Gentian	*Halenia deflexa*	E	Not Mapped
Long-leaved Bluet	*Houstonia longifolia*	E	Mapped
Mountain Firmoss	*Huperzia selago*	E	Mapped
Golden Seal	*Hydrastis canadensis*	E	Mapped
Saltpond Pennywort	*Hydrocotyle verticillata*	T	Mapped
Broad Waterleaf	*Hydrophyllum canadense*	E	Mapped
Creeping St. John's-wort	*Hypericum adpressum*	T	Mapped
Giant St. John's-wort	*Hypericum ascyron*	E	Mapped
St. Andrew's Cross	*Hypericum hypericoides* ssp. *multicaule*	E	Mapped
Mountain Winterberry	*Ilex montana*	E	Mapped
Acadian Quillwort	*Isoetes acadiensis*	E	Mapped
Lake Quillwort	*Isoetes lacustris*	E	Mapped
Small Whorled Pogonia	*Isotria medeoloides*	E	Mapped
Weak Rush	*Juncus debilis*	E	Mapped
Thread Rush	*Juncus filiformis*	E	Mapped
Redroot	*Lachnanthes caroliana*	SC	Mapped
Bead Pinweed	*Lechea pulchella* var. *moniliformis*	E	Mapped
Saltpond Grass	*Leptochloa fusca* ssp. *fascicularis*	T	Mapped
Sea Lyme-grass	*Leymus mollis* ssp. *mollis*	E	Mapped
New England Blazing Star	*Liatris scariosa* var. *novae-angliae*	SC	Mapped
Sandplain Flax	*Linum intercursum*	SC	Mapped
Rigid Flax	*Linum medium* var. *texanum*	T	Mapped
Lily-leaf Twayblade	*Liparis liliifolia*	T	Mapped
Dwarf Bulrush	*Lipocarpha micrantha*	T	Mapped
Heartleaf Twayblade	*Listera cordata*	E	Mapped
Great Blue Lobelia	*Lobelia siphilitica*	E	Mapped
Hairy Honeysuckle	*Lonicera hirsuta*	E	Mapped
Many-fruited False-loosestrife	*Ludwigia polycarpa*	E	Mapped
Round-fruited False-loosestrife	*Ludwigia sphaerocarpa*	E	Mapped
Black-fruited Woodrush	*Luzula parviflora* ssp. *melanocarpa*	E	Mapped
Foxtail Clubmoss	*Lycopodiella alopecuroides*	E	Mapped
Gypsywort	*Lycopus rubellus*	E	Mapped
Climbing Fern	*Lygodium palmatum*	SC	Mapped
Sweetbay Magnolia	*Magnolia virginiana*	E	Mapped
Bayard's Green Adder's-mouth	*Malaxis bayardii*	E	Mapped
White Adder's-mouth	*Malaxis monophyllos* var. *brachypoda*	E	Mapped

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Oysterleaf	*Mertensia maritima*	E	Mapped
Woodland Millet	*Milium effusum*	T	Mapped
Winged Monkey-flower	*Mimulus alatus*	E	Mapped
Muskflower	*Mimulus moschatus*	E	Mapped
Michaux's Sandwort	*Minuartia michauxii*	T	Mapped
Large-leaved Sandwort	*Moehringia macrophylla*	E	Mapped
Red Mulberry	*Morus rubra*	E	Mapped
Alternate-flowered Water-milfoil	*Myriophyllum alterniflorum*	E	Mapped
Farwell's Water-milfoil	*Myriophyllum farwellii*	E	Mapped
Pinnate Water-milfoil	*Myriophyllum pinnatum*	SC	Mapped
Comb Water-milfoil	*Myriophyllum verticillatum*	E	Mapped
Lion's Foot	*Nabalus serpentarius*	E	Mapped
Tiny Cow-lily	*Nuphar microphylla*	E	Mapped
Adder's-tongue Fern	*Ophioglossum pusillum*	T	Mapped
Prickly Pear	*Opuntia humifusa*	E	Mapped
Golden Club	*Orontium aquaticum*	E	Mapped
Violet Wood-sorrel	*Oxalis violacea*	E	Mapped
Ginseng	*Panax quinquefolius*	SC	Mapped
Gattinger's Panic-grass	*Panicum philadelphicum* ssp. *gattingeri*	SC	Mapped
Philadelphia Panic-grass	*Panicum philadelphicum* ssp. *philadelphicum*	SC	Mapped
Long-leaved Panic-grass	*Panicum rigidulum* ssp. *pubescens*	T	Mapped
Silverling	*Paronychia argyrocoma*	E	Mapped
Swamp Lousewort	*Pedicularis lanceolata*	E	Mapped
Hairy Beardtongue	*Penstemon hirsutus*	E	Mapped
Strigose Knotweed	*Persicaria setacea*	T	Mapped
Sweet Coltsfoot	*Petasites frigidus* var. *palmatus*	E	Mapped
Crested Fringed Orchis	*Platanthera cristata*	E	Mapped
Leafy White Orchis	*Platanthera dilatata*	T	Mapped
Pale Green Orchis	*Platanthera flava* var. *herbiola*	T	Mapped
Drooping Speargrass	*Poa saltuensis* ssp. *languida*	E	Mapped
Threadfoot	*Podostemum ceratophyllum*	SC	Mapped
Sea-beach Knotweed	*Polygonum glaucum*	SC	Mapped
Pondshore Knotweed	*Polygonum puritanorum*	SC	Mapped
Braun's Holly-fern	*Polystichum braunii*	E	Mapped
Swamp Cottonwood	*Populus heterophylla*	E	Mapped
Algae-like Pondweed	*Potamogeton confervoides*	T	Mapped
Fries' Pondweed	*Potamogeton friesii*	E	Mapped
Hill's Pondweed	*Potamogeton hillii*	SC	Mapped
Ogden's Pondweed	*Potamogeton ogdenii*	E	Mapped
Straight-leaved Pondweed	*Potamogeton strictifolius*	E	Mapped
Vasey's Pondweed	*Potamogeton vaseyi*	E	Mapped
Sandbar Cherry	*Prunus pumila* var. *depressa*	T	Mapped
Pink Pyrola	*Pyrola asarifolia* ssp. *asarifolia*	E	Not Mapped
Bur Oak	*Quercus macrocarpa*	SC	Mapped
Yellow Oak	*Quercus muehlenbergii*	T	Mapped
Tiny-flowered Buttercup	*Ranunculus micranthus*	E	Mapped
Bristly Buttercup	*Ranunculus pensylvanicus*	SC	Mapped
Maryland Meadow Beauty	*Rhexia mariana*	E	Mapped
Great Laurel	*Rhododendron maximum*	T	Mapped
Capillary Beak-sedge	*Rhynchospora capillacea*	E	Mapped

Common Name	Scientific Name	MESA Status (2010)	Mapped/Not Mapped in *BioMap2*
Inundated Horned-sedge	*Rhynchospora inundata*	T	Mapped
Short-beaked Bald-sedge	*Rhynchospora nitens*	T	Mapped
Long-beaked Bald-sedge	*Rhynchospora scirpoides*	SC	Mapped
Torrey's Beak-sedge	*Rhynchospora torreyana*	E	Mapped
Bristly Black Currant	*Ribes lacustre*	SC	Mapped
Northern Prickly Rose	*Rosa acicularis* ssp. *sayi*	E	Mapped
Toothcup	*Rotala ramosior*	E	Mapped
Seabeach Dock	*Rumex pallidus*	T	Mapped
Swamp Dock	*Rumex verticillatus*	T	Mapped
Slender Marsh Pink	*Sabatia campanulata*	E	Mapped
Plymouth Gentian	*Sabatia kennedyana*	SC	Mapped
Sea Pink	*Sabatia stellaris*	E	Mapped
Wapato	*Sagittaria cuneata*	T	Mapped
Estuary Arrowhead	*Sagittaria montevidensis* ssp. *spongiosa*	E	Mapped
River Arrowhead	*Sagittaria subulata*	E	Mapped
Terete Arrowhead	*Sagittaria teres*	SC	Mapped
Sandbar Willow	*Salix exigua* ssp. *interior*	T	Mapped
Canadian Sanicle	*Sanicula canadensis*	T	Mapped
Long-styled Sanicle	*Sanicula odorata*	T	Mapped
Pod-grass	*Scheuchzeria palustris*	E	Mapped
Northeastern Bulrush	*Scirpus ancistrochaetus*	E	Mapped
Long's Bulrush	*Scirpus longii*	T	Mapped
Papillose Nut Sedge	*Scleria pauciflora*	E	Mapped
Tall Nut-sedge	*Scleria triglomerata*	E	Mapped
Sclerolepis	*Sclerolepis uniflora*	E	Mapped
Wild Senna	*Senna hebecarpa*	E	Mapped
Bristly Foxtail	*Setaria parviflora*	SC	Mapped
Sandplain Blue-eyed Grass	*Sisyrinchium fuscatum*	SC	Mapped
Slender Blue-eyed Grass	*Sisyrinchium mucronatum*	E	Mapped
Large-leaved Goldenrod	*Solidago macrophylla*	T	Mapped
Upland White Aster	*Solidago ptarmicoides*	E	Mapped
Rand's Goldenrod	*Solidago simplex* ssp. *randii* var. *monticola*	E	Mapped
Northern Mountain-ash	*Sorbus decora*	E	Mapped
Small Bur-reed	*Sparganium natans*	E	Mapped
Salt Reedgrass	*Spartina cynosuroides*	T	Mapped
Shining Wedgegrass	*Sphenopholis nitida*	T	Mapped
Swamp Oats	*Sphenopholis pensylvanica*	T	Mapped
Hooded Ladies'-tresses	*Spiranthes romanzoffiana*	E	Mapped
Grass-leaved Ladies'-tresses	*Spiranthes vernalis*	T	Mapped
Small Dropseed	*Sporobolus neglectus*	E	Mapped
American Sea-blite	*Suaeda calceoliformis*	SC	Mapped
Snowberry	*Symphoricarpos albus* var. *albus*	E	Mapped
Eastern Silvery Aster	*Symphyotrichum concolor*	E	Mapped
Crooked-stem Aster	*Symphyotrichum prenanthoides*	T	Mapped
Tradescant's Aster	*Symphyotrichum tradescantii*	T	Mapped
Arborvitae	*Thuja occidentalis*	E	Mapped
Pygmyweed	*Tillaea aquatica*	T	Mapped
Cranefly Orchid	*Tipularia discolor*	E	Mapped
Weft Bristle-fern	*Trichomanes intricatum*	E	Mapped
False Pennyroyal	*Trichostema brachiatum*	E	Mapped

Common Name	**Scientific Name**	**MESA Status (2010)**	**Mapped/Not Mapped in *BioMap2***
Broad Tinker's-weed	*Triosteum perfoliatum*	E	Mapped
Nodding Pogonia	*Triphora trianthophora*	E	Mapped
Northern Gama-grass	*Tripsacum dactyloides*	E	Mapped
Spiked False Oats	*Trisetum spicatum*	E	Mapped
Resupinate Bladderwort	*Utricularia resupinata*	T	Mapped
Subulate Bladderwort	*Utricularia subulata*	SC	Mapped
Mountain Cranberry	*Vaccinium vitis-idaea* ssp. *minus*	E	Mapped
Narrow-leaved Vervain	*Verbena simplex*	E	Mapped
Sessile Water-speedwell	*Veronica catenata*	E	Mapped
Culver's-root	*Veronicastrum virginicum*	T	Mapped
Downy Arrowwood	*Viburnum rafinesquianum*	E	Mapped
Sand Violet	*Viola adunca*	SC	Mapped
Britton's Violet	*Viola brittoniana*	T	Mapped
Barren Strawberry	*Waldsteinia fragarioides*	SC	Mapped
Smooth Woodsia	*Woodsia glabella*	E	Mapped

Non-MESA-listed Species

The habitats of 27 non-MESA-listed wildlife species were included in *BioMap2* as Species of Conservation Concern Core Habitat. Most of these species are SWAP species in greatest need of conservation; a few species are neither MESA-listed nor listed in the Massachusetts SWAP. These few species were included because of emerging concerns about their conservation status in the state.

Non-MESA-listed species were mapped using one of three methods:

- Individual mapping technique: A method that is similar to the delineation of species habitats for MESA-listed species.
- Exemplary mapping technique: The best (most viable) populations for each species were chosen; then, each was mapped using a method similar to delineating species habitats for MESA-listed species.
- Indirect mapping technique: The habitats for these species were assumed to be "swept up" in creating other types of Core Habitat or Critical Natural Landscape.

This section of the technical report deals only with those non-MESA-listed species that were mapped in *BioMap2* using an Individual or an Exemplary mapping technique. SWAP species that were mapped indirectly or were not considered at all are discussed in Section B of the General Methodology chapter, above.

Table 19. Numbers of Non-MESA-listed Species of Conservation Concern mapped explicitly in *BioMap2*.

Taxa	**Non-MESA Species of Conservation Concern**
Amphibians	3
Reptiles	5
Birds	13
Mammals	1
Invertebrates	5
TOTAL	**27**

Amphibians
Two species of non-MESA-listed amphibians, Four-toed Salamander and Northern Leopard Frog, were mapped using an individual technique. The remaining amphibian, Spring Salamander, was mapped using an exemplary technique.

Table 20. Non-MESA-listed amphibians included in *BioMap2*.

Non-MESA-listed Amphibians	Scientific Name	Mapping Technique
Four-toed Salamander	*Hemidactylium scutatum*	Individual
Northern Leopard Frog	*Lithobates pipiens*	Individual
Spring Salamander	*Gyrinophilus porphyriticus*	Exemplary

Reptiles
Five reptile species were mapped: Eastern Ribbon Snake, Smooth Green Snake, Eastern Hognose Snake, Spotted Turtle, and Black Racer. Two of these species (Eastern Ribbon Snake and Smooth Green Snake) were mapped using a method that is similar to the delineation of species habitats (Individual mapping technique). Smooth Green Snake is neither MESA-listed nor a SWAP species.

For Black Racer, an Individual mapping technique was used, but only those areas delineated that were in Core Habitat for other reasons were included in *BioMap2*.

For Eastern Hognose Snake and Spotted Turtle, an Exemplary mapping technique was used.

Table 21. Non-MESA-listed reptiles included in *BioMap2*.

Non-MESA-listed Reptile Species	Scientific Name	Mapping Technique
Spotted Turtle	*Clemmys guttata*	Exemplary
Northern Black Racer	*Coluber constrictor*	Individual (but only in Core Habitat)
Eastern Hognose Snake	*Heterodon platirhinos*	Exemplary
Smooth Green Snake	*Opheodrys vernalis*	Individual
Eastern Ribbon Snake	*Thamnophis sauritus*	Individual

Birds
Thirteen non-MESA-listed bird species were mapped explicitly, with either an Individual or Exemplary mapping technique. Habitat for four of these species were delineated using individual species occurrences (individual in table below) that have been submitted to or are tracked by NHESP. For the remaining nine species, exemplary habitat was delineated by NHESP biologists

using expert knowledge and the best available information. Table 22 lists these species and the mapping technique used. Cerulean Warbler is neither MESA-listed nor a SWAP species.

Table 22. Non-MESA-listed birds included in *BioMap2* and mapped explicitly.

Non-MESA-listed Bird Species	Scientific Name	Mapping Technique
Saltmarsh Sharp-tailed Sparrow	*Ammodramus caudacutus*	Exemplary
Seaside Sparrow	*Ammodramus maritimus*	Exemplary
Ruddy Turnstone	*Arenaria interpres*	Exemplary
Sanderling	*Calidris alba*	Exemplary
Red Knot	*Calidris canutus*	Exemplary
Whip-poor-will	*Caprimulgus vociferus*	Individual
Cerulean Warbler	*Dendroica cerulea*	Exemplary
Snowy Egret	*Egretta thula*	Individual
Laughing Gull	*Larus atricilla*	Individual
Short-billed Dowitcher	*Limnodromus griseus*	Exemplary
Whimbrel	*Numenius phaeopus*	Exemplary
Black-crowned Night-heron	*Nycticorax nycticorax*	Individual
Sora	*Porzana carolina*	Exemplary

Mammals
The only non-MESA-listed mammal included in *BioMap2* was the New England Cottontail.

Documented occurrences of New England Cottontail (*Sylvilagus transitionalis*) from 1980 to 2010 in southeastern Massachusetts and on Cape Cod were used to delineate cottontail habitat. The five observations in southwestern Massachusetts during that period were not used, because the observations did not reflect the amount of habitat that likely exists in this portion of Massachusetts. Other *BioMap2* analyses will likely do a much better job of identifying high priority areas in southwestern Massachusetts for New England Cottontail.

To identify the habitat for New England Cottontail for Core Habitat, the following steps were taken:

- Buffered the historic and recent observations by 1000 meters.
- Removed all areas within 10 meters of development from these polygons.
- Removed all areas of open water from the remaining polygons.
- Clipped out of the area remaining the buffered roads (see Appendix L: Road Buffer Polygon Layer for how the roads were buffered).
- Dissolved all of these polygons, exploded them, and then recalculated the acres of each polygon.
- For the remainder of the analysis, only the polygons that were 100 acres or larger were used.

- For each 100+-acre polygon, the area surrounding each polygon was manually reviewed. If there was contiguous natural habitat beyond the 1000-meter buffer from the actual observation, the original polygon was enlarged to the extent of appropriate habitat. Figure 10 below shows an example of this.

Figure 10. An example of Core Habitat polygon delineated for New England Cottontail.

Invertebrates

Habitats for five species of non-MESA-listed invertebrates were mapped using an Individual mapping technique. Table 23 lists the five species. Sandplain Heterocampa and Gold-spotted Ghost Moth are neither MESA-listed nor SWAP species.

Table 23. Non-MESA-listed invertebrates explicitly included in *BioMap2*.

Non-MESA-listed Invertebrate Species	Scientific Name	Mapping Technique
Little Bluet	*Enallagma minusculum*	Individual
Appalachian Coronet	*Hadena ectypa*	Individual
Sandplain Heterocampa	*Heterocampa varia*	Individual
Two-striped Cord Grass Moth	*Macrochilo bivittata*	Individual
Gold-spotted Ghost Moth	*Sthenopis auratus*	Individual

Section B: Priority Natural Communities

Introduction
Natural communities include distinct assemblages of species (both rare and common) in distinct habitats. NHESP's data layer, Priority Natural Communities, includes most occurrences of the least common community types occurring in Massachusetts, as well as the best (outstanding or exemplary) examples of common (or secure) types of natural communities. NHESP Priority Natural Communities were included in *BioMap2* in order to provide additional identification of important areas for biodiversity in the Commonwealth.

In order to incorporate as much biodiversity as possible, *BioMap2* included the rarest and most viable occurrences of uncommon natural community types as well as exemplary examples of more common community types (together "Priority Natural Communities," as identified by the NHESP ecologist; see Table 24). NHESP's database has extensive records of occurrences of Priority Natural Communities throughout the state; most of these were included in *BioMap2*.

Table 24. Priority Natural Communities included in *BioMap2*.

Natural Community	S Rank
Acidic Graminoid Fen	S3
Acidic Rock Cliff Community	S4
Acidic Rocky Summit/Rock Outcrop Community	S4
Acidic Shrub Fen	S3
Acidic Talus Forest/Woodland	S4
Alluvial Atlantic White Cedar Swamp	S2
Alluvial Hardwood Flat	S2
Alluvial Red Maple Swamp	S3
Atlantic White Cedar Bog	S2
Black Ash Swamp	S2
Black Ash-Red Maple-Tamarack Calcareous Seepage Swamp	S2
Black Gum Swamp	S2
Black Gum-Pin Oak-Swamp White Oak "Perched" Swamp	S2
Black Oak - Scarlet Oak Forest/Woodland	S3S4
Calcareous Basin Fen	S1
Calcareous Forest Seep Community	S2
Calcareous Pondshore/Lakeshore	S2
Calcareous Rock Cliff Community	S3
Calcareous Rocky Summit/Rock Outcrop Community	S2
Calcareous Seepage Marsh	S2
Calcareous Sloping Fen	S2
Calcareous Talus Forest/Woodland	S3
Circumneutral Rock Cliff Community	S3
Circumneutral Rocky Summit/Rock Outcrop Community	S2S3
Circumneutral Talus Forest/Woodland	S3
Coastal Atlantic White Cedar Swamp	S2
Coastal Forest/Woodland	S3
Coastal Interdunal Marsh/Swale	S1
Coastal Plain Pondshore	S2
Cobble Bar Forest	S2
Deep Emergent Marsh	S4

Natural Community	S Rank
Dry Riverside Bluff	S2
Dry, Rich Acidic Oak Forest	S4
Estuarine Intertidal: Brackish Tidal Marsh	S1
Estuarine Intertidal: Coastal Salt Pond Marsh	S2
Estuarine Intertidal: Fresh/Brackish Tidal Swamp	S1
Estuarine Intertidal: Freshwater Tidal Marsh	S1
Estuarine Intertidal: Saline/Brackish Flats	S3
Estuarine Intertidal: Salt Marsh	S3
Estuarine Subtidal: Coastal Salt Pond	S2
Forest Seep Community	S4
Hemlock Ravine Community	S4
Hemlock-Hardwood Swamp	S4
Hickory - Hop Hornbeam Forest/Woodland	S2
High Elevation Spruce - Fir Forest/Woodland	S2
Highbush Blueberry Thicket	S4
High-Energy Riverbank	S3
High-Terrace Floodplain Forest	S2
Inland Acidic Pondshore/Lakeshore	S4
Inland Atlantic White Cedar Swamp	S2
Kettlehole Level Bog	S2
Kettlehole Wet Meadow	S3
Level Bog	S3
Low-Energy Riverbank	S4
Major-River Floodplain Forest	S2
Marine Intertidal: Flats	S4
Marine Intertidal: Rocky Shore	S2
Marine Subtidal: Flats	S4
Maritime Beach Strand Community	S3
Maritime Dune Community	S2
Maritime Juniper Woodland/Shrubland	S1
Maritime Pitch Pine On Dunes	S1
Maritime Rock Cliff Community	S2
Maritime Shrubland Community	S3
Mixed Oak Forest	S5
Northern Atlantic White Cedar Swamp	S2
Northern Hardwoods - Hemlock - White Pine Forest	S5
Oak - Hemlock - White Pine Forest	S5
Oak - Hickory Forest	S4
Oak - Holly Forest / Woodland	S3
Oak - Tulip Tree Forest	S1
Pitch Pine - Scrub Oak Community	S2
Red Maple - Black Ash - Bur Oak Swamp	S2
Red Maple Swamp	S5
Red Oak - Sugar Maple Transition Forest	S4
Rich, Mesic Forest Community	S3
Ridgetop Chestnut Oak Forest/Woodland	S4
Ridgetop Pitch Pine - Scrub Oak Community	S2
Riverine Pointbar And Beach	S3
Riverside Rock Outcrop Community	S3
Riverside Seep	S2
Sandplain Grassland	S1
Sandplain Heathland	S1

Natural Community	S Rank
Scrub Oak Shrubland	S1
Sea-Level Fen	S1
Shallow Emergent Marsh	S4
Shrub Swamp	S5
Small-River Floodplain Forest	S2
Spruce - Fir - Northern Hardwoods Forest	S4
Spruce-Fir Swamp	S3
Spruce-Tamarack Bog	S2
Transitional Floodplain Forest	S2
Wet Meadow	S4
Yellow Oak Dry Calcareous Forest	S2

S-Rank Definitions:

- S1 – Typically 5 or fewer occurrences, very few remaining acres or miles of stream, or especially vulnerable to extirpation in Massachusetts for other reasons.
- S2 – Typically 6-20 occurrences, few remaining acres or miles of streams, or very vulnerable to extirpation in Massachusetts for other reasons.
- S3 – Typically 21-100 occurrences, limited acreage or miles of stream in Massachusetts.
- S4 – Apparently secure in Massachusetts.
- S5 – Demonstrably secure in Massachusetts.

Mapping

In the NHESP database, natural communities are mapped using field data, supplemented for boundary delineation by the most recent aerial photographs available and various other spatial data layers, such as the DEP Wetlands delineations, available in MassGIS. Delineations of large patch and matrix community types are generally mapped conservatively and mapping is limited to known areas where field data are actually taken. All NHESP occurrences of natural communities have been visited by ecologists who supplied data on the sites.

Similar to the system used for ranking of rare species populations, community occurrences were evaluated on a statewide basis using three primary ranking factors: size, condition, and landscape context.

Based on detailed NHESP data on the distribution, composition, and status of natural communities, NHESP currently defines 108 types of terrestrial (upland), palustrine (freshwater wetland), and estuarine (coastal salt-influenced wetland) community types across the Commonwealth. Examples of terrestrial communities include forests, rocky ridgetops, shrublands, and beaches; palustrine (wetland) examples include red maple swamps, bogs, and marshes; and estuarine communities include salt marshes and tidal flats. Natural communities may be restricted or widespread in their distribution across the state. In evaluating sites to survey for the NHESP database, conservation priority is given to types of natural communities with limited distribution— regionally or globally—and to the best examples documented of more common types such as old-growth tracts of widespread forest types. Based on assessment of community size, condition, and landscape context, 782 examples of 94 of these Priority and Exemplary Natural Community types are included as Core Habitat in *BioMap2*. Data on natural communities for *BioMap2* were pulled from the NHESP database on August 5, 2010.

There are a small number (<5%) of "data-sensitive communities" present in the Priority and Exemplary Natural Community database. These communities were not included in *BioMap2* in order to protect individual species in them that might be targeted for illegal harvest. A very few additional occurrences are not included if the community substrate might be too easily damaged by visitors.

Overall, there are 90,535 acres of Priority Natural Communities present within Core Habitat. The tables in Appendix M place the communities into the broader "ecosystem type" used to describe the *BioMap2* project in the summary report.

Section C. Vernal Pool Core Habitats

Vernal pools are small seasonal wetlands that provide important wildlife habitat, especially for amphibians and invertebrate animals that use them to breed. The persistence of populations of vernal pool-breeding species, such as the Blue-spotted Salamander, relies not only on the presence of the vernal pool itself, but also on adjacent upland forest habitat for foraging, overwintering, and successful migration of individuals among pools. Individuals breeding at the different pools interact over time and maintain the overall population as breeding success shifts among pools with changing environmental conditions. For this reason, *BioMap2* analyzed not only the vernal pools, but also the quality of the habitat surrounding the pools and the connections among them. There is no map of all vernal pools in the state, but NHESP biologists have created a Potential Vernal Pool (PVP) database, systematically locating potential vernal pool habitat from aerial photographs.

There are close to 30,000 PVPs that were identified during the vernal pool inventory project. The challenge for *BioMap2* was to identify a model that could be used to prioritize among these many PVPs. Luckily, a paper published in 2007 had tackled exactly this problem in Massachusetts, using the PVP database by researchers at the University of Massachusetts. They developed a "resistant-kernel" modeling approach to develop a model of connectivity for amphibians that breed in vernal pools (Compton *et al.*, 2007). The model in the 2007 paper used information compiled on amphibian habitat and dispersal preferences. It also used two-dimensional land use data (1999 land use/land cover) to create a "cost surface" that represented "the willingness of an animal to cross each cover type, the physiological cost of moving, and the reduction in survival for an organism moving across the landscape" (Compton *et al.*, 2007).

The model scores each vernal pool with a local, neighborhood, and regional score (between 0 and 1). The local score indicates that quality of habitat surrounding each vernal pool, from near 0 (for a pool with no accessible upland habitat) to 1 (for a pool with optimal upland habitat). The neighborhood score given to every vernal pool indicates the number of dispersers each pool was expected to receive directly from populations associated with neighboring pools, based on configuration of adjacent pools and the quality of habitat through which individuals would have to move. Again the value lies between 0 and 1. Finally, the regional score measured the size of pool clusters with a specified level of dispersal among pools (value from 0 to 1).

For our purposes of identifying the areas that would protect not only vernal pools, but also the habitat surrounding vernal pools, the neighborhood scale scores applied to each vernal pool were used to isolate the top 5% of vernal pools (1200) within each ecoregion. We then used the buffer tool (described in Chapter 4, Section B) to identify the intact upland habitat that connects and surrounds these vernal pool clusters to allow for successful breeding, dispersal, overwintering, foraging, and migration. This exercise identified 36,182 acres throughout the state that, if protected, would protect some of the densest and potentially most valuable vernal pool habitat in Massachusetts. Targeting clusters of pools, rather than individual pools, will maximize the resistance and resilience of vernal pool habitats and their resident species in the context of climate change. Table 25 shows the distribution of vernal pool core acres by ecoregion.

Figure 11. Two clusters of vernal pools identified by the model and the upland habitat surrounding and between the pools.

Table 25. Distribution of acres of Vernal Pool Cores by ecoregion.

Ecoregion	Acres
Berkshire Plateau	2,191
Boston Basin and Southern New England Coastal	14,073
Bristol/Narragansett Lowlands	7,450
Cape Cod and Islands	2,281
Connecticut River Valley	2,269
Taconic Mountains	254
Western New England Marble and Berkshire Valleys	1,031
Worcester Plateau	6,632

Section D: Forest Core Habitats

Introduction

Forests are the dominant vegetation type in the eastern United States, and Massachusetts has nearly three million acres of various forest communities (Figure 12). The Commonwealth's extensive forests provide valuable habitat for a wide range of woodland plants and animals. Forest-interior habitat—identified in *BioMap2* as Forest Core—is widely recognized as critically important for species sensitive to forest fragmentation and is becoming increasingly scarce in highly populated regions of the country like Massachusetts. Forest-interior habitats are the areas least impacted by roads, residential and commercial development, and other fragmenting features. Many bird species that breed in Massachusetts are sensitive to forest fragmentation, including Ovenbirds, Scarlet Tanagers, and many woodland warblers. Negative results of fragmentation include edge effects such as nest predation by species associated with development such as skunks, raccoons, and house cats; and nest parasitism by species such as the Brown-headed Cowbird that lay their eggs in the nests of other bird species and reduce their reproductive success. Our analyses were designed to identify the largest and least fragmented forest-interior habitats across Massachusetts, the most important as priorities for protection. With this approach, *BioMap2* Forest Cores include, for example, beech-birch-maple forests in western Massachusetts, oak-hickory forests in central Massachusetts, and oak-pine forests in eastern Massachusetts. By identifying important forested areas, we can protect both known and unknown biodiversity, serving as a "coarse filter" for biodiversity conservation.

Methods

Forest Cores capture the largest and highest integrity patches of forest cover in Massachusetts. We used the UMass CAPS Index of Ecological Integrity (IEI) to identify the most intact and least disturbed upland and wetland forests across the state (See Chapter 2, Section D for details on the CAPS IEI methods). In order to achieve representation of Cores across the state, we used the "integrated" scaling of IEI (see Figure 13). This version of the IEI combines the statewide scores with ecoregional (for upland forest) or watershed (for forested wetlands) scaling of the IEI scores. The higher of the two scores is selected for each pixel and then the scores are rescaled from 0 to 1. We chose the integrated scaling to capture the most intact areas of forest-interior habitat in each ecoregion, as well as the best examples statewide.

Using the integrated IEI raster layer, high integrity forest cover was identified by extracting forest and forested wetland cells with an integrated IEI value greater than 0.8. The results represent the most intact 20% of the overall forested landscape across the state and within each of the ecoregions (see Figure 14). The integrated IEI was used to ensure we captured Forest Cores in each of the ecoregions across the state, as each represents unique forest biodiversity and should be represented in *BioMap2*.

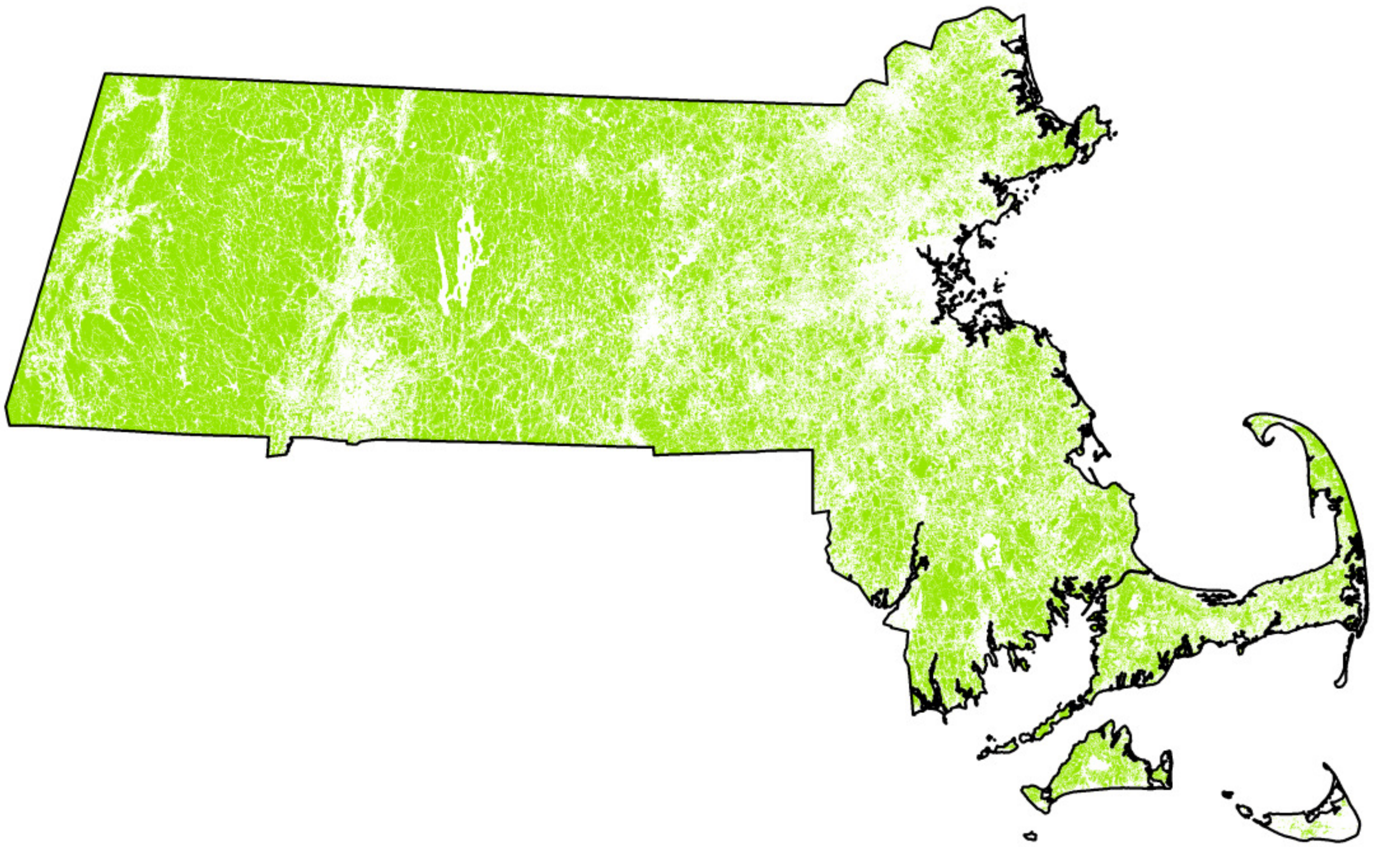

Figure 12. Forest Cover within Massachusetts.
(Upland Forest and Forested Wetlands, as mapped by the MassGIS 2005 Land Use/Land Cover data)

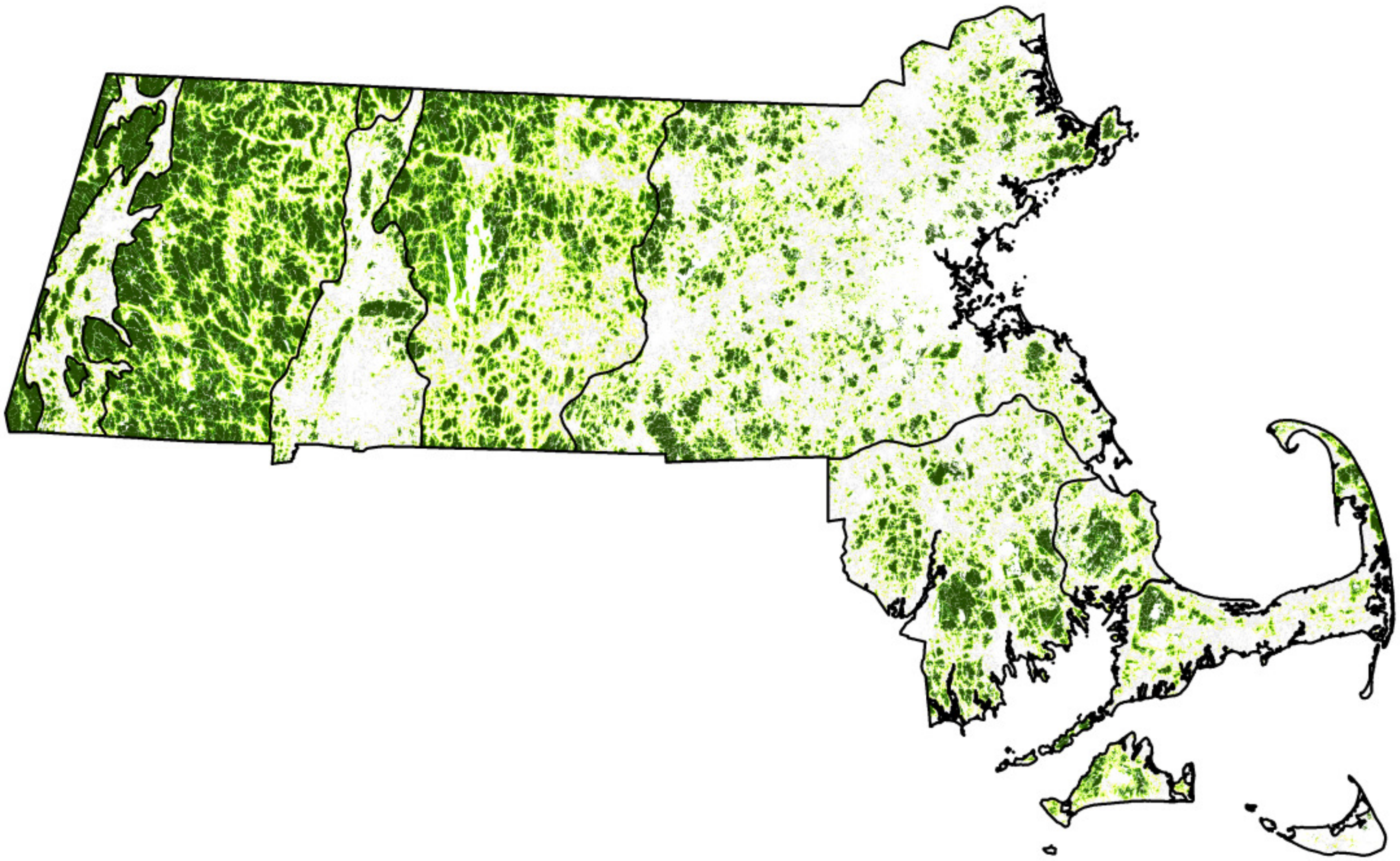

Figure 13. Forests scored by the Index of Ecological Integrity (IEI).
(Darkest green= highest integrity)

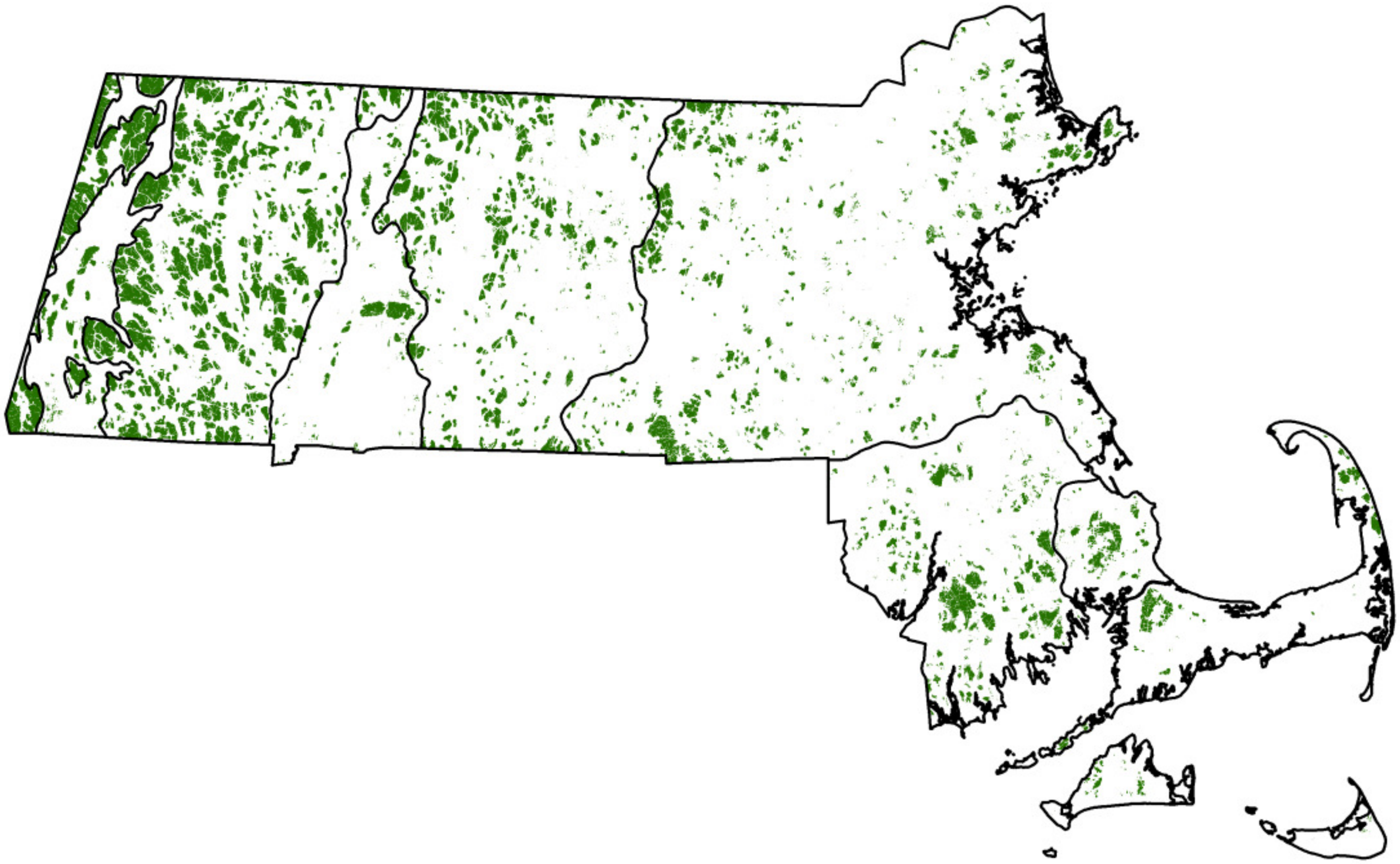

Figure 14. Forests with the top 20% Integrated IEI scores.
(combining statewide and ecoregional scaling)

To identify the largest examples of high-integrity forest, the resulting raster was converted to a vector layer. Polygons within 60 meters of each other were merged (aggregated). The purpose of aggregating polygons was to combine forest-interior patches that were separated by short distances of natural cover, such as a small stream or other natural habitat type, and are therefore minimally fragmented by these features. The 60-meter distance limit enabled Cores to merge across small streams and wetlands with a single pixel width, but kept Forest Cores separate when they were divided by larger rivers, other large natural features, or areas of less intact habitat defined by lower IEI.

Before calculating the final acreage of Forest Cores, a GIS "erase" was performed to remove roads and development that had been absorbed into Cores through the aggregation process. This ensured that no Forest Core polygons accidently included bisecting roads so that even Cores within 60 meters of each other across roads were separated. Acreages were then calculated and all Cores less than 100 acres were deleted from the dataset to facilitate subsequent analyses. Forest Cores were then assigned to a single ecoregion, according to the centroid of the Forest Core polygon. A total of 879 preliminary Forest Cores totaling 584,019 acres were identified in this analysis (Table 26). Final *BioMap2* Forest Core selection, described below, was based on polygon size thresholds defined for each ecoregion.

Table 26. Summary table of all preliminary Forest Cores >100 acres, showing number of Cores and total acres, by ecoregion.

Ecoregion	Number of Cores	Total Acres
Berkshire Plateau	238	230,697
Boston Basin and Southern New England Coastal	234	92,165
Bristol Lowland/Narragansett Lowland	101	47,555
Cape Cod and Islands	54	22,019
Connecticut River Valley	34	15,955
Taconic Mountains	21	53,839
Western New England Marble Valleys	23	11,790
Worcester Plateau	174	109,999
Total	**879**	**584,019**

Forest Core Selection

A review of the Forest Cores in each ecoregion showed that Class 6 roads (from the MassGIS EOT Roads layer) fragmented Cores excessively in certain areas of the state, such as around Mt. Greylock and the Quabbin Reservoir, where this road class often represented small dirt roads. To remedy that effect, a manual review of Cores was performed. In the manual review, Cores divided by Class 6 roads were merged into a single multipart polygon. Likewise, Cores were merged across powerlines less than 60 meters in width (according to 2005 orthophotos). Table 26 shows the number, total area, and distribution of preliminary Forest Cores across ecoregions after this manual adjustment.

A series of selections based on Forest Core size and ecoregion were then applied to the remaining set of Forest Cores. The top 10% of Cores by size were selected in each ecoregion. This selection was supplemented by a selection based on minimum acreage size (see Table 27 and Figure 15). These minimum size thresholds were based on research showing that Forest Cores as small as 500 acres provide effective forest-interior habitat. Adding the minimum acreage threshold served to improve Forest Core representation in the eastern Massachusetts and valley ecoregions. The process also added very large Cores in the Taconic Mountains ecoregion, such as Mt. Greylock, where selecting the largest 10% of the polygons did not work effectively to select from a very small number of very large polygons (*i.e.*, they were nearly all large and important). Polygons that met either the largest 10% or minimum size criteria per ecoregion defined the final set of *BioMap2* Forest Cores (Figure 16).

Table 27. Forest Core minimum size by ecoregion.

Ecoregion	**Minimum Size Threshold (acres)**
Berkshire Plateau	2,500
Southern New England Coastal and Boston Basin	500
Bristol Lowland/Narragansett Lowland	500
Cape Cod and Islands	500
Connecticut River Valley	500
Taconic Mountains	3,000
Western New England Marble Valleys	500
Worcester Plateau	1,500

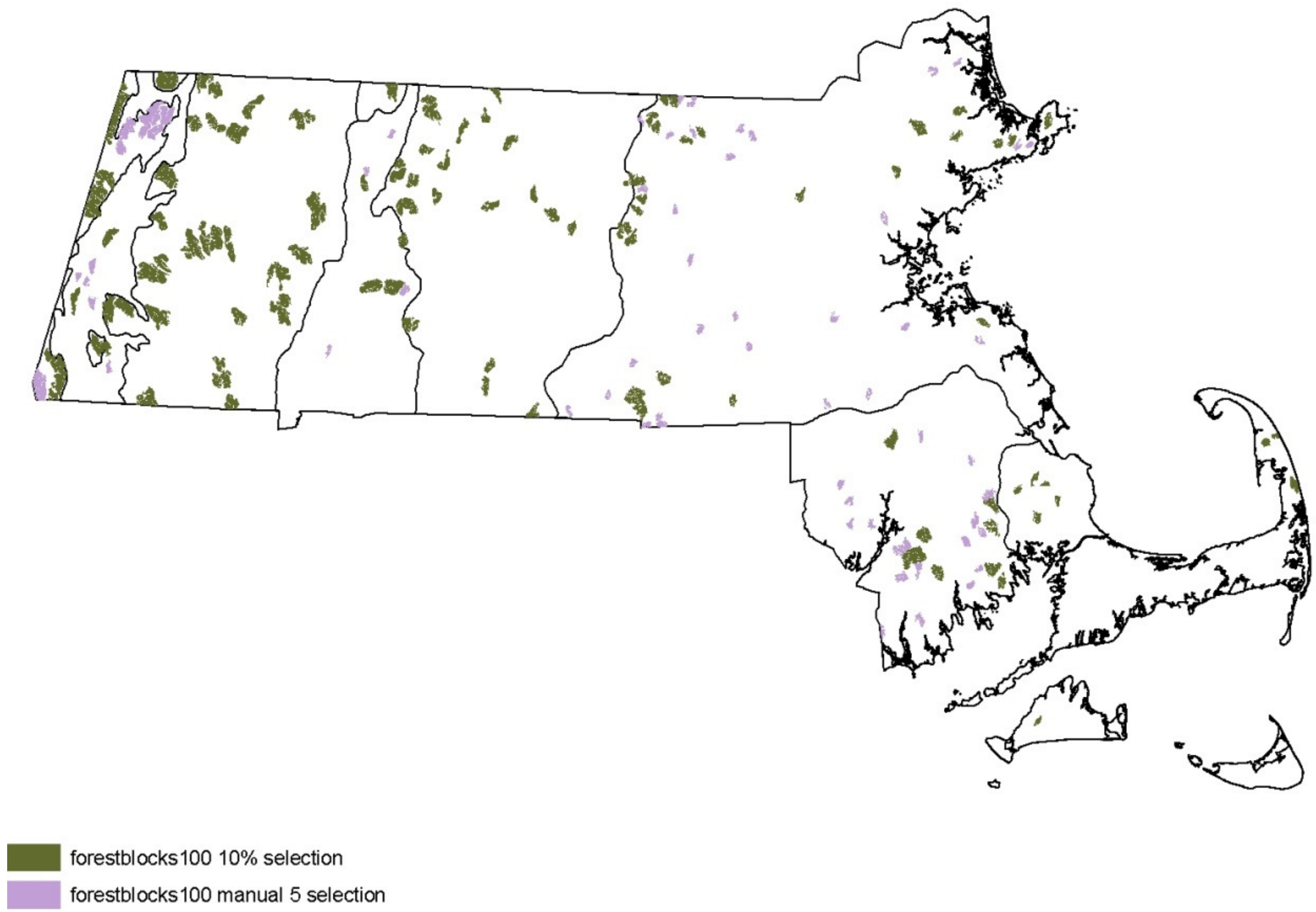

Figure 15. Forest Core selection criteria.

In green are the Cores within the top 10% by size for each ecoregion. In purple are the Cores that were added to the final selection using minimum size thresholds per ecoregion.

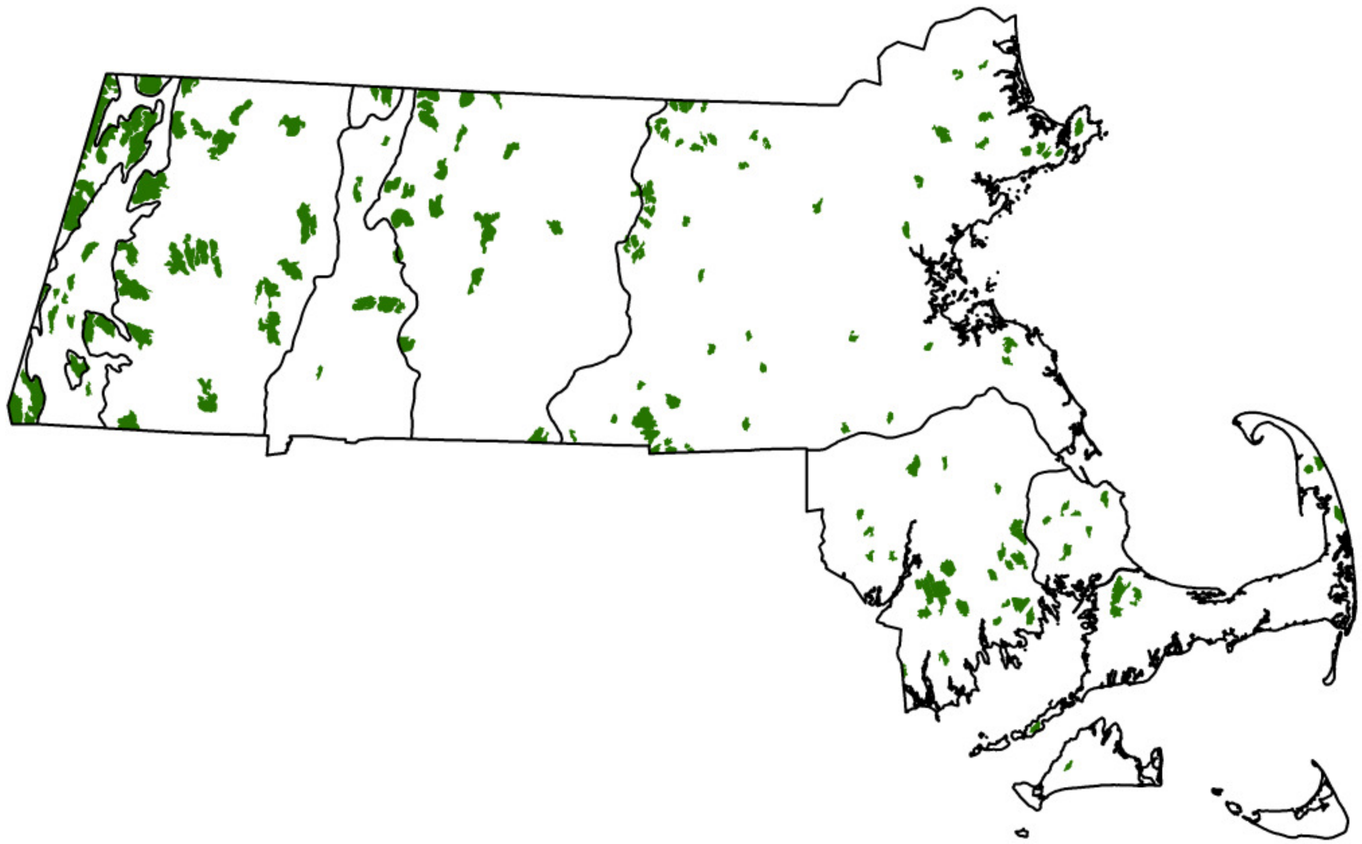

Figure 16. Final selection of Forest Cores
based on the largest 10% in each ecoregion, complemented by minimum size thresholds per ecoregion, and refined (post-processing) to define functional conservation units.

Final Forest Cores and post-processing
Selected Cores were reviewed through automated and manual post-processing steps to smooth and consolidate polygon boundaries, with the goal of creating consolidated and simplified Forest Core boundaries with solid interiors useful for conservation applications.

Particular attention was paid to the effect of Class 6 roads on the Forest Core periphery. The perimeter was edited to remove gaps created by Class 6 roads when those roads were not accompanied by development. Where Class 5 roads perforated the Core boundary, the boundary was left as defined by the IEI even where no development was apparent from the 2005 orthophotos, as we lack information to consistently distinguish levels of impact within the class 5 road category.

The Cores were also edited manually along ecoregional boundaries, where artifacts of the IEI rescaling resulted in non-contiguous Core boundaries across ecoregional boundaries in some places. Core boundaries were also edited to either exclude small irregularities around the perimeter, or fill in gaps and lobes within the overall shape of the Core. Edits were made to follow forest land cover types as shown in the orthophotos.

Five Forest Cores were added along the state boundary where small interior habitats within Massachusetts connected to large high-integrity forests in surrounding states.

These post-processing steps resulted in Forest Cores with lower edge-to-area ratios and solid interiors—optimal conservation units. However, while dominated by high-integrity forest acres, the final Cores do contain minimal areas of forest cover with IEI scores < 0.8 and minimal acres of other natural land cover types as a result of these steps.

After post processing, the final selections resulted in 163 Forest Cores totaling 325,449 acres, representing just over 10% of Massachusetts' forests (Figure 16, Table 28).

Table 28. Final Forest Core selection, after post-processing.

Ecoregion	**# Cores**	**Minimum Acres**	**Maximum Acres**	**Average Acres**	**Total Acres**
Berkshire Plateau	24	2,535	8,610	4,188	100,520
Western New England Marble Valleys	7	563	2,031	1,104	7,727
Bristol Lowland/Narragansett Lowland	27	569	3,118	1,271	34,319
Cape Cod and Islands	13	518	4,745	1,208	15,704
Connecticut River Valley	7	543	3,218	1,508	10,556
Southern New England Coastal Plains and Boston Basin	56	548	4,424	1,046	58,576
Taconic Mountains	10	595	9,987	5,056	50,555
Worcester Plateau	19	1,043	5,966	2,500	47,492
Total	**163**				**325,449**

Discussion

Massachusetts' nearly 3,000,000 forested acres provide numerous values, including wildlife habitat and biodiversity. *BioMap2* includes a conservative subset, just over 10%, of Massachusetts forests that provide the highest quality forest-interior habitat across Massachusetts. Additional and more expansive forest areas are included in the Landscape Block component of *BioMap2*. Forest Cores, as the most intact forest-interior habitats in Massachusetts, are crucial areas for the long-term persistence of forest-interior species and other species and ecological processes. They are a relatively rare and diminishing feature of the Massachusetts landscape, as roads and development fragment some of our last remaining intact habitats. Forest Cores are therefore high priorities for land protection.

Section E: Wetland Core Habitats

Introduction

BioMap2 Core Habitat includes a statewide assessment of the most intact wetlands in Massachusetts. This analysis identified the least disturbed wetlands—Wetland Cores—those with the most intact buffers and little fragmentation or other stressors associated with development. These wetlands are most likely to support critical wetland functions (*i.e.*, natural hydrologic conditions, diverse plant and animal habitats, etc.) and are most likely to maintain these functions into the future. To identify these high-quality wetlands, *BioMap2* incorporated the University of Massachusetts Conservation Assessment and Prioritization System (CAPS) Index of Ecological Integrity (IEI, see Chapter 2, Section D). The analysis combined individual wetland types (*e.g.,* shrub swamps, forested wetlands, marshes, bogs) into contiguous wetland complexes. To enhance the biodiversity value of selected wetlands as Core Habitat, further analyses were conducted to represent wetlands within the varied ecological settings found in Massachusetts, determined by geology and elevation, as different plant and animal assemblages occur in these unique settings. By mapping the most intact wetlands in each ecological setting, *BioMap2* identifies wetlands that support the broadest spectrum of wetland biodiversity, both currently and into the future, which will help prioritize conservation of wetland diversity in the context of climate change.

Methods

The analysis for Wetland Cores was based upon the Massachusetts DEP 1:12,000 wetland data layer (see Table 29). Inland wetland types (for example, Deep Marsh or Shrub Swamp) were selected from this data layer and dissolved in GIS to form "wetland complexes." This was done before the wetland prioritization process so that *BioMap2* included or excluded entire and contiguous wetlands, rather than partial wetlands. Where wetlands were separated by no more than 100 meters of open water, they were combined into the same "wetland complex" unit. This was done to ensure wetlands that are closely connected hydrologically were treated as one unit in the analysis.

Table 29. Size and distribution of DEP wetland types included in Wetland Cores analysis.

Wetland Type	# of Wetlands	Maximum Area (Acres)	Total Area (Acres)	Percent of Statewide Total
Bog	1,360	154	5,411	1%
Deep Marsh	13,657	332	34,903	8%
Shallow Marsh, Meadow or Fen	21,859	248	47,911	11%
Shrub Swamp	33,263	285	76,980	17%
Wooded Swamp Coniferous	5,494	246	23,894	5%
Wooded Swamp Deciduous	62,497	632	194,490	43%
Wooded Swamp Mixed Trees	14,905	431	67,167	15%
Total	**153,035**	**--**	**450,757**	**--**

The wetland complex data layer contained 110,265 polygons and totaled 450,586 acres. Small wetlands were removed from the dataset using a 10-acre size threshold. Once these small wetlands were screened out, the wetlands dataset was reduced from 450,586 acres to 302,521 acres, and the number of individual complexes was reduced from 110,265 to just 7,544, a much more reasonable set for analysis.

Representation of Ecological Settings (*i.e*., Ecological Land Units, or ELUs)

To enhance the biodiversity value of wetlands selected as Core Habitat, further analyses were conducted to identify and select wetlands within the varied ecological settings found in Massachusetts, determined by geology and elevation, as different plant and animal assemblages occur in these unique physical settings. For instance, 108,000 acres of wetlands occur on the sandy soils of southeastern Massachusetts in an elevation range between 20 and 800 feet. By contrast, fewer than 8,000 acres of wetlands are found on marble or calcareous bedrock in western Massachusetts between 800 and 1,700 feet. By mapping the most intact wetlands distributed across all ecological settings, *BioMap2* identifies wetlands that support the broadest spectrum of wetland types and wetland biodiversity, both currently and into the future. These intact wetlands in diverse settings may be thought of as representing the "ecological stage," and are most likely to support a diversity of wetland types over time, even as different plant and animal species (the "actors" on the ecological stage) shift in response to climate change (see Climate Change, Chapter 2, Section C).

To classify wetland complexes by their dominant physical setting, they were categorized by elevation class and geology type using the Ecological Land Unit categories and classification developed by The Nature Conservancy's Eastern Division (see Appendix D). That classification identifies elevation ranges that determine the distribution of ecological communities, and ecologically meaningful associations of bedrock and surficial geology types. Complexes were assigned elevation classes based on the following categories using the Massachusetts 1:5,000 Digital Elevation Model (Figure 17). Polygons that fell into multiple classes were assigned to a single class based on the polygon centroid.

Elevation classes

a. Coastal zone 0-20'
b. Low elevation 20-800'
c. Mid elevation 800-1700'
d. Mid-high 1700-2500' and High elevation > 2500' (these two classes were grouped, since there is very little elevation > 2500' in Massachusetts)

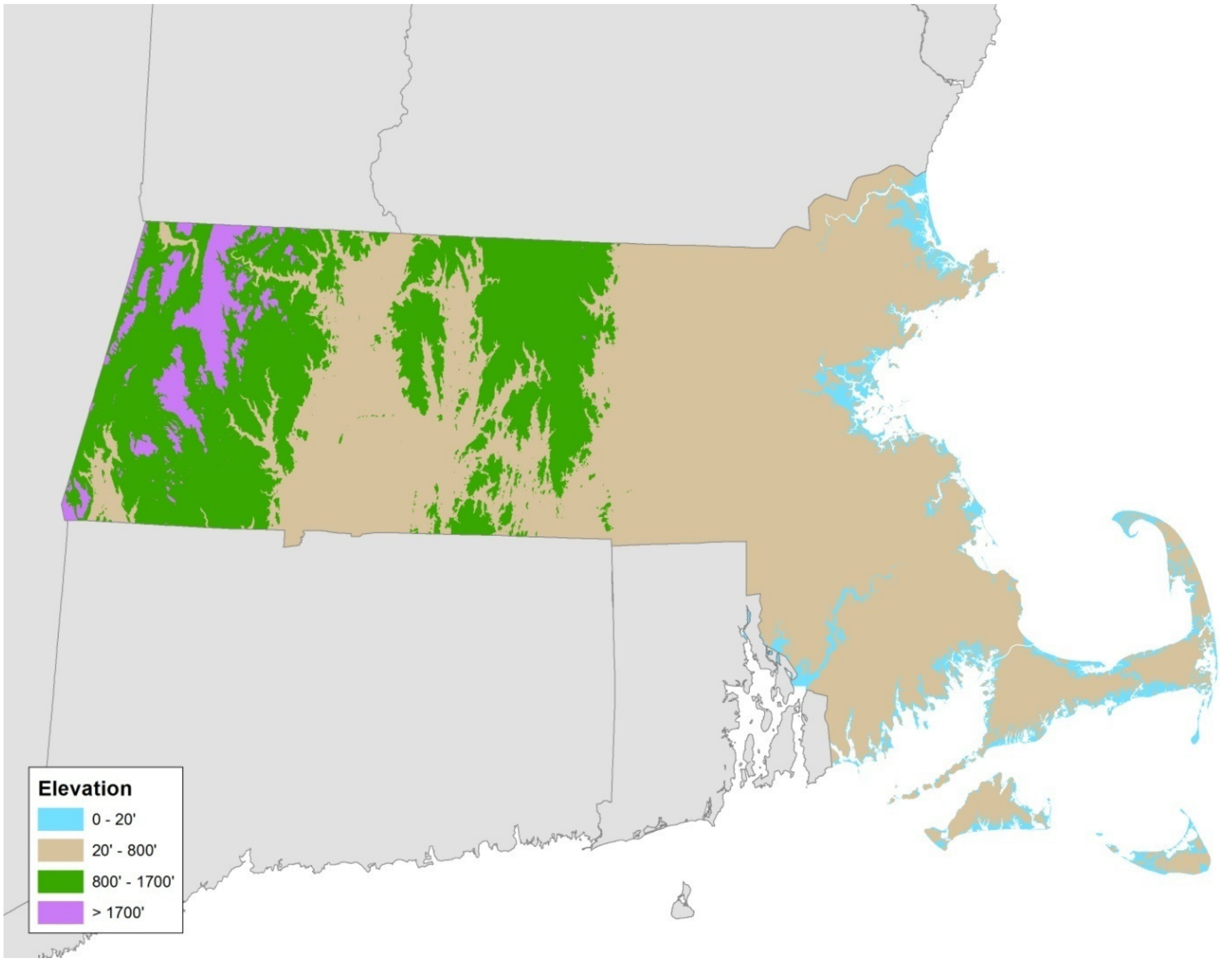

Figure 17. Elevation zones used to assign ELU type to wetland complexes.

Geology data was derived from the MassGIS bedrock lithology layer, originally obtained from USGS and based upon source data ranging from 1:100,000 to 1:500,000 (Figure 18). Where deep sediments prevail over bedrock as drivers of soil characteristics, 1:1 M USGS surficial Quaternary sediments dataset was used to map coarse and fine sediments. To assign geology type, acres of each geology type were tabulated for each wetland complex polygon. Geology classes were assigned significance in order of their rarity, with calcareous types most limited in distribution and acidic types most widely distributed. Where polygons contained two or more geology types, the single most significant geology type was assigned to that wetland complex polygon if it accounted for at least 25% of the complex area.

Geology classes (listed here in order of significance)

a. Calcareous sedimentary/metasedimentary
b. Moderately calcareous sedimentary/metasedimentary
c. Mafic/intermediate granitic and Ultramafic (combined two classes here)
d. Fine sediments
e. Coarse sediments
f. Acidic granitic and Acidic sedimentary/metasedimentary (combined two classes here)

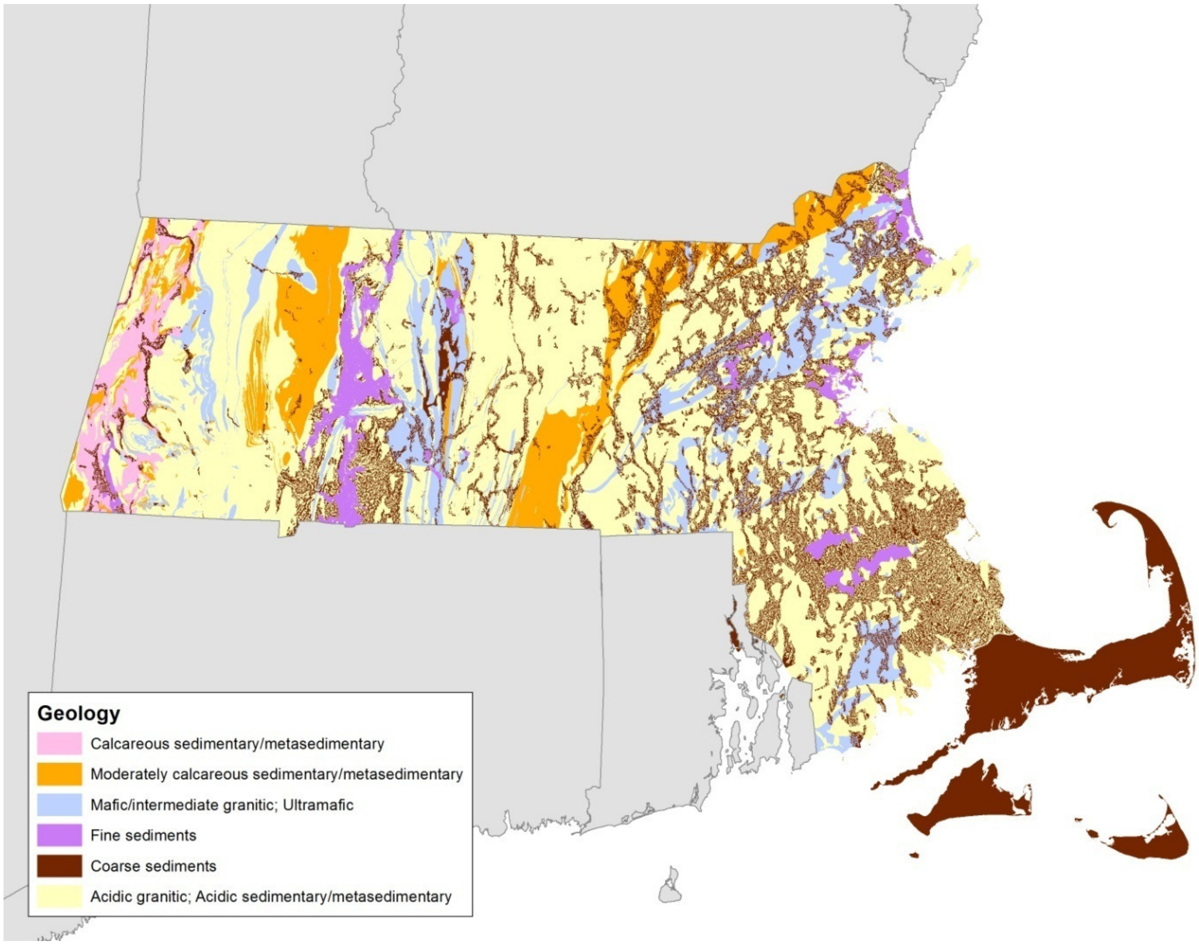

Figure 18. Distribution of geology types used to assign ELUs to wetland complexes.

The elevation and geology analyses described above resulted in wetland complexes categorized into 19 unique Ecological Land Unit (ELU) classes (*e.g.*, 20-800' and Coarse Sediments, or 800-1700' and Acidic Granitic or Acidic Sedimentary/Metasedimentary). Table 30 shows the list of 19 unique ELU settings and the distribution of wetland complexes above 10 acres within these groupings.

Table 30. Wetland Core selection by ELU type. This table shows the breakdown of wetland complexes > 10 acres by ELU type. ELU selection of wetland complexes for *BioMap2* was based on either the top IEI decile or top quartile (selection threshold for each ELU type indicated in red and bold) depending on the rarity of the ELU type.

ELU	# Wetland Complexes	Total Acres	% Total Acres	IEI threshold (statewide scaling) Top decile	IEI threshold (statewide scaling) Top quartile	# Selected Wetland Cores	Selected Acres	% of Total Selected Acres
0-20' and Acidic Granitic or Acidic Sed/Metased	59	2,780	1%	0.73	**0.61**	15	1,842	2%
0-20' and Coarse Sediments	308	10,500	3%	0.63	**0.47**	77	5,000	6%
0-20' and Fine Sediments	36	1,563	1%	0.69	**0.55**	9	936	1%
0-20' and Mafic/intermediate granitic or Ultramafic	24	648	< 1%	0.72	**0.58**	6	125	< 1%
0-20' and Moderately Calcareous Sed/Metased	3	94	< 1%	0.58	**0.53**	1	69	< 1%
20-800' and Acidic Granitic or Acidic Sed/Metased	1,531	58,523	19%	**0.73**	0.58	154	14,901	17%
20-800' and Calcareous Sed/Metased	58	3,273	1%	0.80	**0.68**	15	1,842	2%
20-800' and Coarse Sediments	2,594	108,237	36%	**0.61**	0.44	260	27,043	31%
20-800' and Fine Sediments	309	23,101	8%	**0.67**	0.48	31	10,380	12%
20-800' and Mafic/intermediate granitic or Ultramafic	719	32,151	11%	**0.75**	0.58	72	7,051	8%
20-800' and Moderately Calcareous Sed/Metased	342	10,908	4%	0.72	**0.57**	86	3,940	4%
800-1700' and Acidic Granitic or Acidic Sed/Metased	818	24,913	8%	**0.83**	0.74	82	4,010	5%
800-1700' and Calcareous Sed/Metased	197	7,572	3%	0.70	**0.56**	50	3,116	4%
800-1700' and Coarse Sediments	155	8,608	3%	0.65	**0.57**	39	4,828	5%
800-1700' and Mafic/intermediate granitic or Ultramafic	101	2,377	1%	0.83	**0.76**	26	870	1%
800-1700' and Moderately Calcareous Sed/Metased	148	3,331	1%	0.81	**0.71**	37	829	1%
> 1700' and Acidic Granitic or Acidic Sed/Metased	73	2,023	1%	0.87	**0.82**	19	731	1%
> 1700' and Mafic/intermediate granitic or Ultramafic	67	1,886	1%	0.89	**0.85**	17	603	1%
> 1700' and Moderately Calcareous Sed/Metased	2	32	< 1%	0.87	**0.86**	1	15	< 1%
Total	7,544	302,521	100%			997	88,130	100%

Selection of Wetland Cores using Index of Ecological Integrity (IEI), by ELU type
Next, wetland complexes were scored using the University of Massachusetts Conservation Assessment and Prioritization System (CAPS) Index of Ecological Integrity (IEI, see Chapter 2, Section D). The mean IEI was calculated for each wetland complex (*i.e.,* mean of all pixel scores within the complex) using both statewide scaling and ecoregional scaling rescaled to eight ecoregions. These scores were used to select wetland complexes for inclusion in *BioMap2* as Wetland Cores.

Using the mean IEI scores for each wetland complex from the statewide scaling, the top quartile (top 25%) of wetlands within less common ELU groups (defined as ELU groups accounting for less than 10% of the statewide wetland area) was selected as Wetland Cores. For all other ELU groups, those more common in Massachusetts, a smaller percentage, the top decile (top 10%), was used. Table 30 indicates the IEI thresholds used to select the highest scoring complexes within each ELU group. Of the 302,521 acres of wetlands in the full wetland complex dataset, 88,130 acres were selected through this process.

Selection by Ecoregion
To make certain selected wetlands were well distributed across ecoregions, the top decile of wetland complexes in each ecoregion were selected for inclusion as wetland cores, using the mean ecoregionally scaled IEI for each wetland complex. One hundred and thirty eight Wetland Cores, totaling 6,708 acres, were added as a result of this ecoregion-based selection (Table 31). As a second step in this ecoregional balancing, the limited set of wetlands in the Taconic Mountains ecoregion were reviewed and added if they proved to be in good landscape context according to the 2005 orthoimagery. In the Cape Cod and Islands ecoregion, the acreage threshold was lowered from 10 to 5 acres to allow for the generally smaller size of wetlands in this ecoregion, which also added additional Wetland Cores to *BioMap2*.

Final Wetland Cores
Finally, selected wetlands were reviewed on screen using 2005 orthoimagery. Some selected wetlands in Southeast Massachusetts were found to include cranberry bogs. These were likely misclassified in the DEP wetlands data. As a final processing step, these wetlands were either excluded or edited to remove cranberry bogs from the final set of wetland cores.

The net result of all wetland complex selections, combining ELU stratification and ecoregional balancing and including final editing, are reported in Table 31. The final set of Wetland Cores totals 92,862 acres. Table 32 shows the final breakdown of wetlands selected for *BioMap2* by DEP wetland type and by ecoregion.

Table 31. Acreages of final wetland cores. After selecting the highest ranked wetlands within each ELU group, an additional 6,708 acres of wetlands were selected using the ecoregionally-scaled IEI, while an additional 1,093 acres of wetlands were added in the Taconic Mountains and Cape Cod and Islands to improve representation across ecoregions.

Ecoregions	Top 10% of all ELU types (both rare and common)	Top 10-25% of rare ELU types	Top 10% of wetlands by Ecoregional IEI (NOT already identified by ELU analysis)	Additional Ecoregional Balancing	Grand Total
Berkshire Plateau	4,781	1,741	1,081		7,603
Boston Basin and Southern New England Coastal	20,010	2,838	2,531		25,379
Bristol Lowland/ Narragansett Lowland	30,481	1,582			32,064
Cape Cod and Islands	3,451	1,005	113	885	5,454
Connecticut River Valley	2,527		717		3,243
Taconic Mountains	28	58	26	205	317
Western New England Marble Valleys	4,183	3,085		3	7,272
Worcester Plateau	7,906	1,385	2,240		11,531
Total	**73,367**	**11,694**	**6,708**	**1,093**	**92,862**

Discussion

This series of analyses resulted in the inclusion of 92,862 acres of Wetland Cores in *BioMap2* Core Habitat. This set of wetlands is representative of the full suite of wetland types defined in the original DEP wetland types (bogs, swamps, etc.) as shown in Table 32. Because these wetlands represent the full suite of physical settings defined by elevation and geology (Table 30), if they are effectively conserved, they serve to protect both current and future wetland biodiversity. This set of wetlands is well distributed throughout the state and across ecoregions. These wetlands acres added to and complemented wetlands included in *BioMap2* through rare species habitats and priority natural communities.

Table 32. Selected Wetland Cores by ecoregion and DEP wetland type. Total wetland core acres reported here do not include 57 acres of open water and other mapped land uses included during manual revision of wetland cores.

	Ecoregion	Bog	Deep Marsh	Shallow Marsh Meadow or Fen	Shrub Swamp	Wooded Swamp Coniferous	Wooded Swamp Deciduous	Wooded Swamp Mixed Trees	Total
Total Wetland Acres in Massachusetts	Berkshire Plateau	663	3,217	4,838	8,259	7,516	6,075	3,975	34,544
	Boston Basin and Southern New England Coastal	1,376	12,472	22,842	27,153	2,740	96,358	17,919	180,860
	Bristol Lowlands/Narragansett Lowlands	1,007	4,422	6,001	10,453	3,355	49,842	27,741	102,820
	Cape Cod and Islands	489	1,707	2,906	7,719	1,238	4,707	2,163	20,930
	Connecticut River Valley	222	1,608	2,990	4,933	952	14,070	1,931	26,706
	Taconic Mountains	1	88	49	238	39	497	81	993
	Western New England Marble Valleys	44	1,563	2,741	6,537	929	6,025	3,497	21,337
	Worcester Plateau	1,608	9,826	5,545	11,690	7,126	16,919	9,862	62,575
	Total	5,411	34,904	47,911	76,982	23,895	194,493	67,169	450,765
Wetland Cores (Acres)	Ecoregion	Bog	Deep Marsh	Shallow Marsh Meadow or Fen	Shrub Swamp	Wooded Swamp Coniferous	Wooded Swamp Deciduous	Wooded Swamp Mixed	Total*
	Berkshire Plateau	271	721	1,388	2,092	1,746	782	604	7,603
	Boston Basin and Southern New England Coastal	215	1,669	3,707	4,792	313	12,156	2,526	25,377
	Bristol Lowlands/Narragansett Lowlands	411	1,120	1,343	2,288	1,816	14,625	10,411	32,012
	Cape Cod and Islands	169	251	916	1,893	360	1,025	837	5,450
	Connecticut River Valley	13	85	356	497	425	1,538	331	3,243
	Taconic Mountains		45	18	82	9	123	39	317
	Western New England Marble Valleys	11	724	1,061	2,277	461	1,228	1,509	7,272
	Worcester Plateau	553	2,795	1,344	2,197	1,686	1,719	1,236	11,531
	Grand Total	1,641	7,410	10,133	16,118	6,815	33,196	17,493	92,805
Wetland Cores (% of total)	Ecoregion	Bog	Deep Marsh	Shallow Marsh Meadow or Fen	Shrub Swamp	Wooded Swamp Coniferous	Wooded Swamp Deciduous	Wooded Swamp Mixed	Total
	Berkshire Plateau	41%	22%	29%	25%	23%	13%	15%	22%
	Boston Basin and Southern New England Coastal	16%	13%	16%	18%	11%	13%	14%	14%
	Bristol Lowland/Narragansett Lowland	41%	25%	22%	22%	54%	29%	38%	31%
	Cape Cod and Islands	34%	15%	32%	25%	29%	22%	39%	26%
	Connecticut River Valley	6%	5%	12%	10%	45%	11%	17%	12%
	Taconic Mountains	0%	51%	37%	35%	22%	25%	49%	32%
	Western New England Marble Valleys	24%	46%	39%	35%	50%	20%	43%	34%
	Worcester Plateau	34%	28%	24%	19%	24%	10%	13%	18%
	Grand Total	30%	21%	21%	21%	29%	17%	26%	21%

Section F: Aquatic Core Habitats

BioMap2 Aquatic Core is composed of several separate analyses of aquatic resources, each targeting different sets of species. The following sub-analyses were conducted separately and then brought together in order to assemble the final Aquatic Core data layer:

1. Analysis to identify high-quality habitat supporting four anadromous fish species (Rainbow Smelt and three SWAP fish species indicated in Table 33 below).
2. Analysis to identify high-quality stream habitat supporting the remaining 13 non-MESA-listed fish species using the DFW Fisheries Section database and expert review by the DFW Fisheries Section.
3. Enhancements to Living Waters streams and to small or short stream segments for MESA-listed fish species.
4. Delineation of other MESA-listed aquatic species (includes 139 species).

After the stream segments or aquatic resources were identified by the above analyses, additional steps were taken to delineate the final Aquatic Core polygons. These steps are detailed below.

Finally, an upland buffer to the Aquatic Core was created using the buffer tool described in Chapter 4, Section B. This Aquatic Buffer is part of Critical Natural Landscape.

Table 33. Non-MESA-listed fish species included in *BioMap2*.

Common Name	Scientific Name	Subset	Identification Method
Blueback Herring	*Alosa aestivalis*	Anadromous	Use of DMF database and CT River*
Alewife	*Alosa pseudoharengus*	Anadromous	Use of DMF database and CT River*
American Shad	*Alosa sapidissima*	Anadromous	Use of DMF database and CT River*
American Eel	*Anguilla rostrata*	Inland streams	Fisheries database queries and expert review
White Sucker	*Catostomus commersoni*	Inland streams	Fisheries database queries and expert review
Slimy Sculpin	*Cottus cognatus*	Inland streams	Fisheries database queries and expert review
Banded Sunfish	*Enneacanthus obesus*	Inland streams	Fisheries database queries and expert review
Creek Chubsucker	*Erimyzon oblongus*	Inland streams	Fisheries database queries and expert review
Swamp Darter	*Etheostoma fusiforme*	Inland streams	Fisheries database queries and expert review
Tessellated Darter	*Etheostoma olmstedi*	Inland streams	Fisheries database queries and expert review
Common Shiner	*Luxilus cornutus*	Inland streams	Fisheries database queries and expert review
Blacknose Dace	*Rhinichthys atratulus*	Inland streams	Fisheries database queries and expert review
Sea Lamprey	*Petromyzon marinus*	Inland streams	Fisheries database queries and expert review
Longnose Dace	*Rhinichthys cataractae*	Inland streams	Fisheries database queries and expert review

Common Name	Scientific Name	Subset	Identification Method
Atlantic Salmon	*Salmo salar*	Restoration	Manual selection / confirmation with DFW anadromous fish biologist
Eastern Brook Trout	*Salvelinus fontinalis*	Inland streams	Fisheries database queries and expert review
Creek Chub	*Semotilus atromaculatus*	Inland streams	Fisheries database queries and expert review
Fallfish	*Semotilus corporalis*	Inland streams	Fisheries database queries and expert review

Anadromous Fish

Anadromous fish are an important part of the aquatic biodiversity of Massachusetts. These species hatch in coastal ponds and rivers, then travel to the ocean where they spend most of their lives. Upon reaching maturity, they migrate up coastal rivers to spawn in the same river or pond where they were born.

Anadromous rivers for inclusion in *BioMap2* were identified for Rainbow Smelt, American Shad, Alewife, and Blueback Herring. Atlantic and Shortnose Sturgeon, both anadromous, are MESA-listed species, and habitats for these species were mapped according to rare species protocols (see Species of Conservation Concern section above). Atlantic Salmon are included in coldwater tributaries where they are stocked, since juvenile salmon are resident in these habitats for several years.

River selection and the spatial extent of anadromous runs were based on a review of various datasets by The Nature Conservancy's freshwater ecologist Alison Bowden. Rivers for Alewife, Blueback Herring, and American Shad were identified using base data from the Northeast Aquatic Connectivity Initiative, which recorded rivers with a presence or absence of these species (NEAFWA Aquatic Connectivity Anadromous Fish Presence data [computer files]. The Nature Conservancy Eastern Freshwater Program, 2011. Source data ASMFC 2006). This initial presence/absence data was reviewed and edited according to the best available knowledge about the current status of these runs, including run count data and habitat assessments. Figure 19 shows the rivers selected for anadromous fish and included in Aquatic Core.

<u>American Shad</u>

Selection of runs for shad was based on personal communication with Phil Brady at MA Division of Marine Fisheries as well as fish counts at hydro dams for the Connecticut and Merrimack Rivers. Selection was targeted at places with self-sustaining populations and apparent suitable habitat; shad are formally counted only on the Connecticut and Merrimack Rivers, so judgment and local knowledge (*e.g.*, personal knowledge from Alison Bowden and postings to fishing blogs) were used to supplement data.

<u>River Herrings (Alewife and Blueback Herring)</u>

For river herrings, runs were selected that have consistently been the strongest in the state, as well as representing all the major watersheds where these species occur. Note that few locations are consistently counted and that comparison can be difficult, so this is a largely a qualitative method. Also referenced was Belding's report upon the history, present condition, and possibility of development of the alewife fishery of Massachusetts 1912-1920 for historical context.

For river herrings, no runs were selected in the north coastal basin because the status of river herring there is quite poor due to a combination of passage barriers, flow conditions, and water quality (Purinton, *et al.* 2003). This condition is long standing and restoration efforts have been made, but to date have not been successful. No runs were selected on the Islands because freshwater habitats are limited, although river herring do occur there and probably spawn in fair numbers in some of the coastal ponds, at least in seasons where pond openings and salinity favor successful spawning.

Technical reports referenced:

TR-15 Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A survey of anadromous fish passage in coastal Massachusetts: Part 1. Southeastern Massachusetts.

TR-16 Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A survey of anadromous fish passage in coastal Massachusetts: Part 2. Cape Cod and the Islands.

TR-17 Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A survey of anadromous fish passage in coastal Massachusetts: Part 3. South Coastal.

TR-18 Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A survey of anadromous fish passage in coastal Massachusetts: Part 4. Boston and North Coastal.

Tim Purinton, Frances Doyle and Dr. Robert D. Stevenson. 2003. Status of River Herring on the North Shore of Massachusetts.

David L. Belding. 1920. A Report upon the Alewife Fisheries of Massachusetts. Commonwealth of Massachusetts, Department of Conservation, Division of Fisheries and Game.

Rainbow Smelt

Rainbow Smelt runs are based on a review of GIS data from a Massachusetts Division of Marine Fisheries (DMF) survey of Gulf of Maine coastal streams which documented areas of egg deposition (TR-30). River/estuary systems with a minimum of 4,000 m^2 (aggregate) of occupied spawning habitat in Table 2.1 of that document were selected. The definitive source for designated smelt runs is TR-30; DMF considers all runs referenced in TR-30 as priorities for regulatory purposes. Buzzards Bay sites were added using TR-15 notes on smelt, as well as recent photos of Weweantic River smelt eggs at Horseshoe dam posted on the web by a local resident. For selected runs, the extent of the run was defined in GIS as extending from the upstream point of the data supplied by DMF to the mouth of the river.

Technical reports and websites referenced:

TR-30 Chase, B. C. 2006. Rainbow smelt (*Osmerus mordax*) spawning habitat on the Gulf of Maine coast of Massachusetts. PDF. (3,621 kb) http://www.mass.gov/dfwele/dmf/publications/technical.htm

TR-15 Reback, K.E., P.D. Brady, K.D. McLaughlin, and C.G. Milliken. 2004. A survey of anadromous fish passage in coastal Massachusetts: Part 1. Southeastern Massachusetts.

http://glooskapandthefrog.org/weweantic%20river%20revisited.htm

Atlantic and Shortnose Sturgeon
Both runs indicated in the Atlantic State Marine Fisheries Commission (ASMFC) data were selected, since they were confirmed with NHESP records.

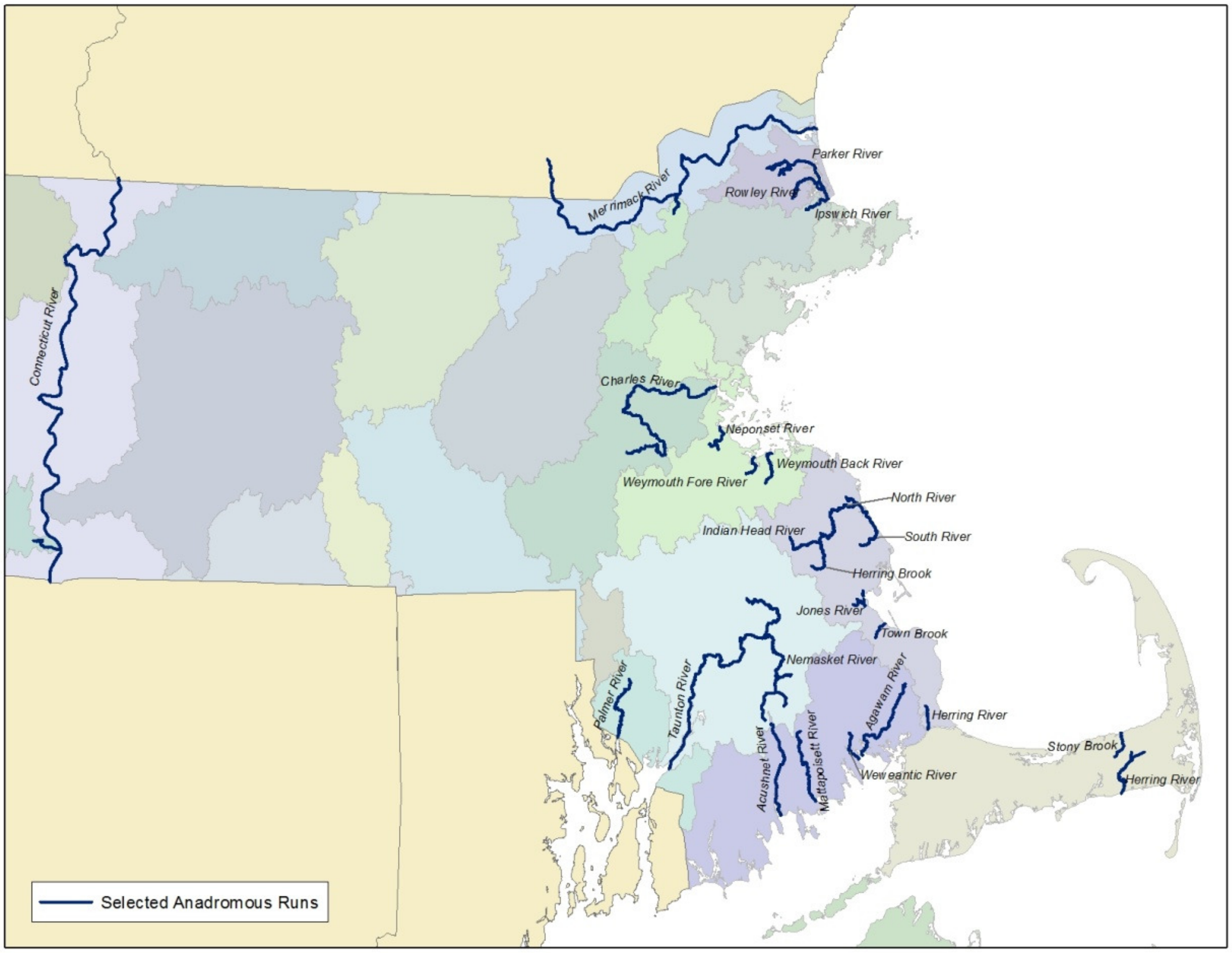

Figure 19. All anadromous runs selected for inclusion in Aquatic Core.

GIS Methods for Anadromous Fish Mapping

Spatial delineation of the anadromous fish runs began with GIS data from TNC's Northeast Connectivity (NEC) Initiative. It is based on the National Hydrography Dataset, a 1:100K dataset for rivers. The first step of the GIS analysis was to review and select from within the NEC data the appropriate rivers and extents for the species in question. This was done with the aid of Alison Bowden, TNC freshwater ecologist. Once the proper extents were defined within this 1:100K dataset, they were transferred to a stream centerline dataset based upon the 1:25K MassGIS Hydrography dataset. A 30-meter fixed-width buffer was applied to selected stream centerlines. Open water polygons from the DEP wetlands data that fell within this buffer were selected, then edited to snip off long tributaries before also being buffered by 30 meters. The result of these two buffering steps was to create a polygon layer incorporating the best representation of the stream with a 30-meter buffer from its banks.

Next, wetlands that intersected this stream buffer were selected from the DEP wetland dataset. A dissolved version of the DEP wetlands was used to ensure that all contiguous wetlands were captured. Several secondary selections and reviews were necessary to ensure accuracy of selection. Where long tails of wetlands were selected, these were curtailed through manual editing. Finally, the selected wetlands were unioned with the buffered stream polygon, and the resulting layer was dissolved. The end result is a polygon layer of the open water portion of streams, a 3-meter buffer of those streams, and the wetlands that intersect that buffer.

A set of post-processing decisions were made during the final editing of this layer. They are in summary:

- Cranberry bogs were not included in the wetland selection.
- Where contiguous wetlands extend far from the original anadromous run, they were clipped at the first road.
- The same treatment (clipping at the first road) was applied to large tributaries and their associated wetlands.
- Enclosed gaps between wetlands and the buffered stream channel were not filled in; however, if there were wetlands within this gap, they were added to the final layer.
- Certain rivers were clipped at the dam or bridge rather than the ocean.
    - Taunton - clipped at bridge that according to convention is the extent of the Taunton River (it is the extent of the Wild and Scenic designation).
    - Charles River - cut off at dam.
- Beaches, dunes, and barrier beaches were erased from the final layer where they fell beyond the 30-meter buffer.
- The Merrimack, Charles, Agawam, and Taunton rivers were reviewed manually and development along the banks was excised from the final layer.

As an example, Figure 20 below shows the detailed components of the anadromous core for the Mattapoisett River. Figure 21 shows the dissolved union of these components, and the extent that was added to Aquatic Core.

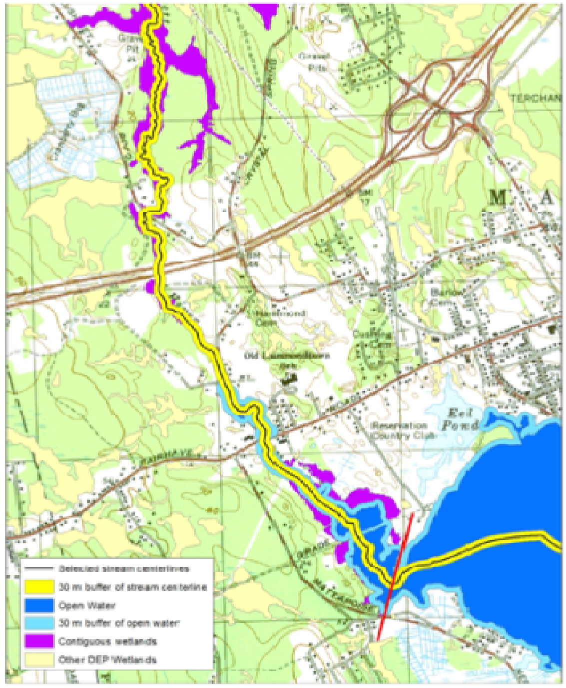

Figure 20. Components of the Aquatic Core for the mouth of the Mattapoisett River.

Figure 21. Aquatic Core extent for the Mattapoisset River.

Identification of Selected High-Priority Habitat for Remaining Non-MESA-listed SWAP Fishes

There are over 3000 data points in the DFW Fisheries Section database. Information contained in the database includes a unique sample ID for each point, link to the SARIS/PALIS stream code, date of sample, town, method of sample (*e.g*., barge shocking, backpack shocking, gillnetting), the species and length of every fish captured during the sample, duration of sample effort (seconds) at each point, and crew names, as well as several other fields. Given such detailed information, it was possible to use the species present, species richness, and density to identify a subset of the sample points that would likely identify high-quality stream habitat that should be targeted for protection.

Identification of the target points was the first of a three-step process to identify high-quality habitat. The second step involved manual review of every target to identify if the point represented high-quality habitat. The third step involved identifying the upstream and downstream river/stream segments that likely have similar habitat characteristics. It is important to note that while this process identified high-quality habitat for the 14 "inland fish" (non-MESA-listed), there are other methods that could and will be used to identify "high-quality" stream habitat. The high-quality habitat identified does not represent all of the important habitat needed to protect these 14 fish species.

The set of targets were identified using the following criteria:

- Points where 100% of fish caught were Brook Trout and/or Slimy Sculpin and are in the top 25% most dense samples (catch per unit effort) - 64 points identified.
- Tthe top 10% of points ranked by density of Brook Trout only (Brook Trout catch per unit effort) - 116 points identified.
- The top 10% of points ranked by fluvial SWAP density (number of fluvial species at a site/number of seconds of electro-shocking). Fluvial SWAP fish included all species except the anadromous species from Table 33 - 153 points identified.

There was overlap in some of the points selected. Table 34 indicates how many were identified within multiple queries.

Table 34. Queries used to identify targets supporting non-MESA-listed fish species.

Query / Selection Criteria	Number of Targets
100% Brook Trout and Slimy Sculpin (Top 25%) **ONLY**	14
Brook Trout Density (Top 10%) **ONLY**	53
Fluvial SWAP Density (Top 10%) **ONLY**	140
Fluvial SWAP Density (Top 10%) and Brook Trout Density (Top 10%)	13
100% Brook Trout and Slimy Sculpin (Top 25%) and Brook Trout Density (Top 10%)	50

These criteria identified 270 targets. Every one of those targets was investigated and the species composition, the aerial photo, and expert knowledge of each sample point and stream were used to determine if the target should be selected as the "seed" of a stream segment that extends from that point. When investigating each point, a variety of factors were considered, including:

- Relative abundance of fish species present at point;
- Presence of species that indicated poor habitat quality;
- Amount of urban / suburban development located near the sample point; and
- "Point-specific" knowledge derived from field notes or familiarity of the DFW Fisheries Section staff with the point.

The following staff from the Division of Fisheries and Wildlife took part in the expert panel review of each of the targets: Kristin Black, Leanda Fontaine, Alicia Norris, Dana Ohman, and Todd Richards. Caleb Slater and Steve Hurley of the Division reviewed the streams selected for Atlantic Salmon and the streams and rivers in the Southeast District, respectively.

After an initial full-day retreat concentrating on selection criteria, the remaining MassWildlife districts were used to divide up and complete analysis. Dana Ohman conducted this analysis for DFW's Western District. Leanda Fontaine and Alicia Norris conducted this analysis in coordination with Todd Richards for the Central District. Todd Richards, Leanda Fontaine, Alicia Norris, Dana Ohman, and Kristin Black conducted the analysis for the Connecticut Valley district. Todd Richards, Leanda Fontaine, and Alicia Norris conducted this analysis for the Northeast and Southeast districts. James DeNormandie provided GIS support throughout these meetings.

In the eastern portion of the state, the fluvial richness and the density of Brook Trout fell so much that there were almost no points identified by the criteria in the Northeast and Southeast DFW Districts. In these areas and a few watersheds in the west, the top 10%, or no fewer than two points, were selected from each of the following watersheds in order to represent more fully the biodiversity of the state's aquatic systems: Bashbish, Buzzards Bay, Cape Cod and Islands, Charles, Farmington, Ipswich, Kinderhook, Merrimack, North Coastal, Neponset, Parker, Shawsheen, South Coastal, and Taunton. Each of these additional targets was analyzed manually as described above, to determine if they should serve as the seed of an aquatic core.

Once the "seed" points were selected, we made another sweep to identify the extent of the river upstream and downstream of the point that would be included in the Aquatic Core. This process was also expert-driven, although considerations such as the following were used when determining how far upstream or downstream to map from the "seed" sample point:

- Nearby sample points that indicated a consistently high fluvial species richness that extended upstream or downstream until the richness dropped off.
- Presence of a dam that was known to disrupt passage of fish between upstream and downstream segments.
- Intersection with a higher order stream whose characteristics and species composition are known to be different than those found at the "seed" sample.
- Consideration of the species composition and abundance at adjacent sample sites paying specific attention for presence of fluvial species in high numbers, or of habitat-generalist species, which indicates a degradation of habitat or water quality at that sample.

Enhancements to Living Waters Data and MESA-listed Fish Species Habitats
The final Living Waters GIS data layer created by NHESP in 2003 included areas key to the protection of rare species and exemplary aquatic habitats. For the purposes of *BioMap2*, we identified the portions of the Living Waters project that could be updated or superseded using the current information present in the Heritage databases, and those portions of the analysis that cannot be replicated and should be incorporated into *BioMap2*.

Information that was updated using more current information:

- Rare aquatic plants
- Rare aquatic fish
- Rare aquatic invertebrates – freshwater mussels
- Rare aquatic invertebrates - non-insect aquatic invertebrates
- Exemplary aquatic habitats – invertebrate habitat in rivers (coarse-filter rivers)
  The location of rare odonate habitat was used as an indicator for those portions of rivers that should be included in Living Waters. All rare odonate habitat will be considered and added into *BioMap2* as a result of inclusion of the species habitats of odonates.
- Exemplary aquatic habitats – habitat for inland fishes
  We incorporated information from a database that the Fisheries section maintains to consider multiple non-listed SWAP fish species. This analysis will be used to replace the analysis in Living Waters that identified important habitat for inland and coastal fishes.

Living Waters analyses that were preserved in *BioMap2*:

- Exemplary aquatic habitats – invertebrate habitat in streams (coarse-filter streams)
  A large amount of work was conducted for Living Waters to identify high-quality small streams (1st and 2nd order) throughout the state. From an initial 697 reaches of small acidic perennial streams, a subset was identified and then verified using field work to represent very high quality aquatic habitat. These stream segments were retained and entered into *BioMap2*.
- Exemplary aquatic habitats – lake and pond habitats (coarse-filter lakes)
  A large amount of work was also conducted for Living Waters to identify high-quality lake and pond habitat throughout the state. The final lakes and ponds that were selected and verified using field work were added directly to *BioMap2*.
- Difference between rare species habitat in Living Waters and current version of rare species habitat: We conducted an analysis of all of the rare species habitat identified in Living Waters that was no longer present in the aquatic rare species “footprint” as represented by the current Heritage databases. We identified those portions of the *old* rare species footprint (as depicted by Living Waters) that were no longer being identified by the current footprint. Then we analyzed why these areas dropped from consideration. In the cases where an aquatic habitat was “down-ranked” (*e.g.*, due to increased impacts of development), the removal from *BioMap2* was allowed to remain. However, in some cases where the habitat was removed only because the rare species observation had become out of date (historic) but the habitat was otherwise intact, we elected to maintain this Living Waters habitat in *BioMap2*.

To create a more robust network of Aquatic Core, stream segments below a minimum length were extended through a GIS analysis that used the CAPS Index of Ecological Integrity to identify adjacent high quality stream habitat. This treatment was applied to stream segments from the Living Waters "Coarse Filter Streams" (described in section 3.1b of the Living Waters Technical Report) as well as MESA-listed fish habitats.

There are 84 Living Waters coarse-filter stream segments; all are below 0.5 miles in length and total 24 miles. Fish species habitats total 22,190 acres, which translates roughly to 463 miles in length. Of these fish habitat polygons, those 20 acres in size or less were selected for extension, excluding lakes or ponds.

The CAPS-integrated IEI data was averaged across stream segments. Segments with scores >0.8, or the top 20% of streams, were selected and dissolved. Where these high-scoring streams intersected or were within 30 m of targeted short segments, they were selected as potential stream additions. The length of stream additions varied according to the extent of high-scoring adjacent habitat.

Where Living Waters segments had low IEI scores and no high-scoring adjacent habitat, they were deleted. Eighteen such segments were deleted for this reason. No MESA-listed fish habitat was deleted due to low IEI scores.

Finally, potential stream extensions were reviewed by DFW/NHESP fisheries biologist Kristen Black and manually edited for corrections.

Inclusion of Remaining MESA-listed Aquatic Species Habitats
A subset of all of the MESA-listed species live all of, or a portion of their lives, in aquatic habitat. We isolated these 139 species and identified the 30 meters of upland adjacent to their species habitats. These species habitats plus the 30 meters were included as Aquatic Core Habitat (see Appendix N for list of these species). While almost all of these polygons were included, some of the specific species habitats were removed for species such as Crooked-stem Aster, which can exist in areas that are removed from the hydrological network of rivers, streams, and wetlands. For instance, some occurrences were mapped on hillsides where only a seep was present. These types of species habitat polygons were removed since it does not make sense to include them as part of Aquatic Core.

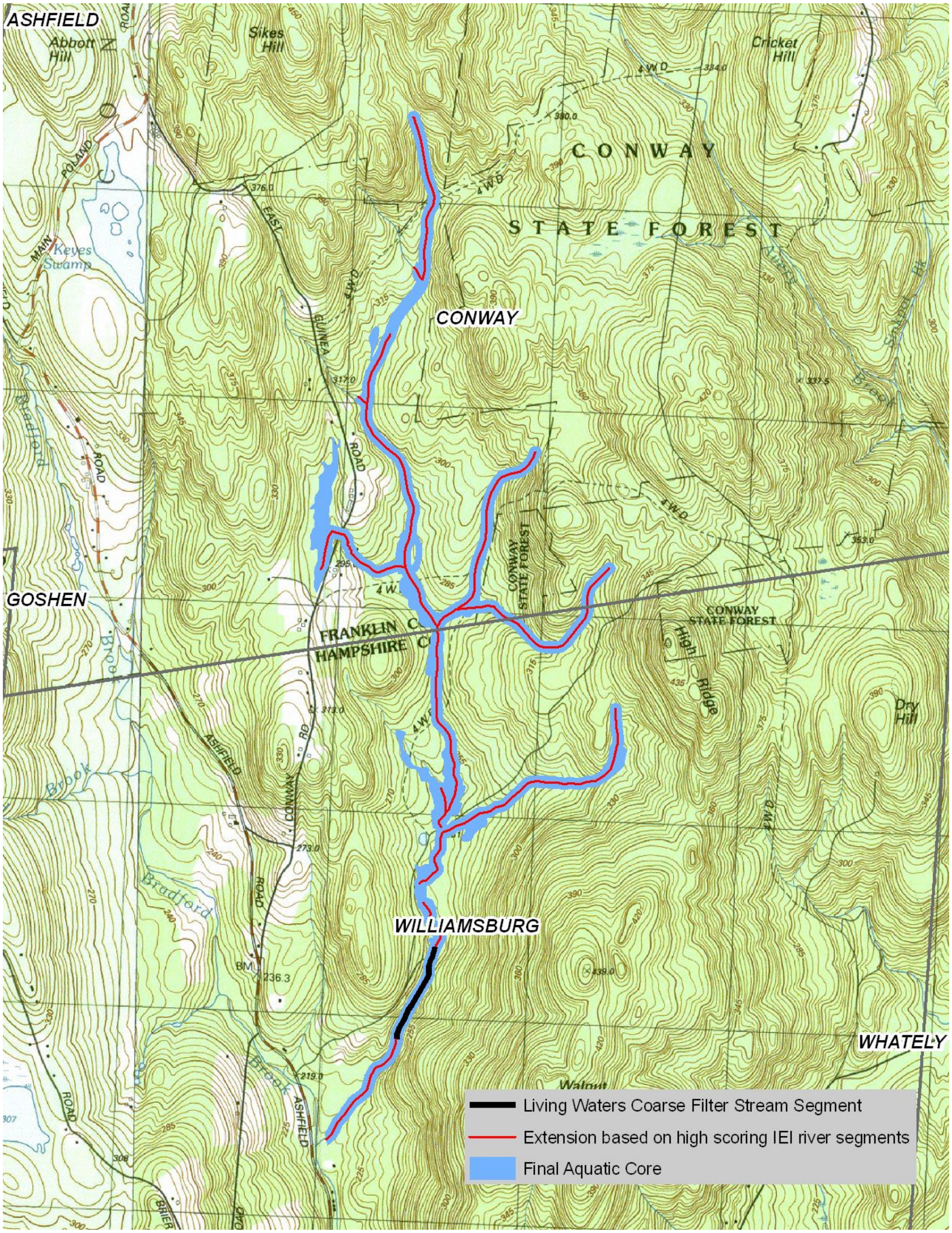

Figure 22. Example of a Living Waters coarse-filter stream segment that was "enhanced."

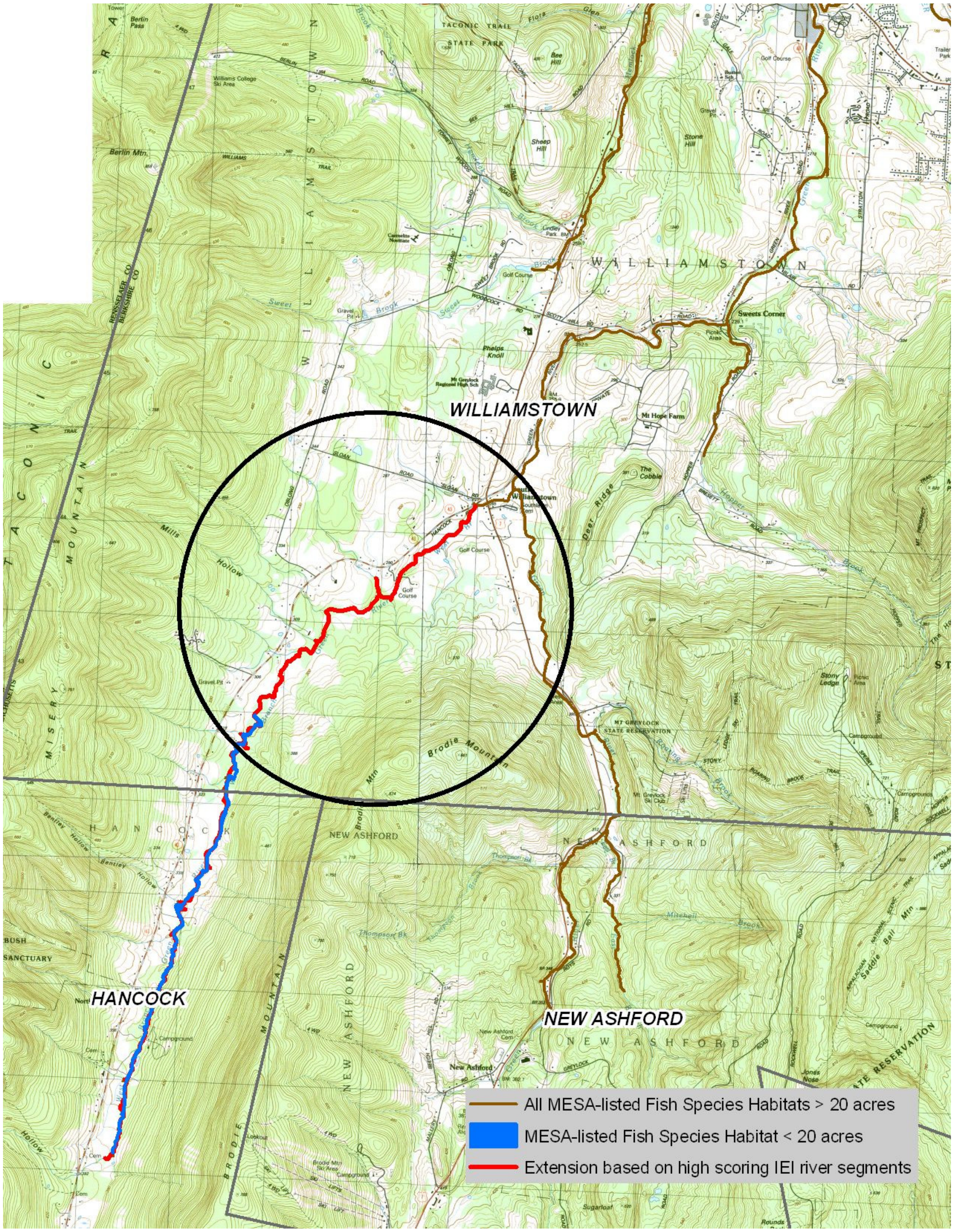

Figure 23. An example of a high-quality stream segment that bridged the gap between two MESA-listed fish species habitats.