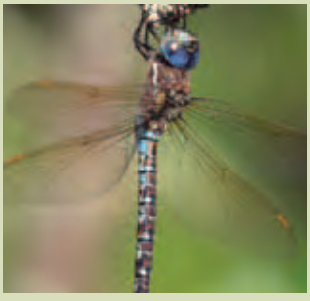
BioMap 2

CONSERVING THE BIODIVERSITY OF MASSACHUSETTS IN A CHANGING WORLD



MA Department of Fish & Game | Division of Fisheries & Wildlife | *Natural Heritage & Endangered Species Program* ▪ The Nature Conservancy

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Commonwealth of Massachusetts
Department of Fish & Game

Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries & Wildlife

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BioMap2

CONSERVING THE BIODIVERSITY OF MASSACHUSETTS IN A CHANGING WORLD

A project of the

Massachusetts Department of Fish & Game and
The Nature Conservancy

Produced by the

Natural Heritage & Endangered Species Program of the
Massachusetts Division of Fisheries & Wildlife and the
Massachusetts Program of The Nature Conservancy

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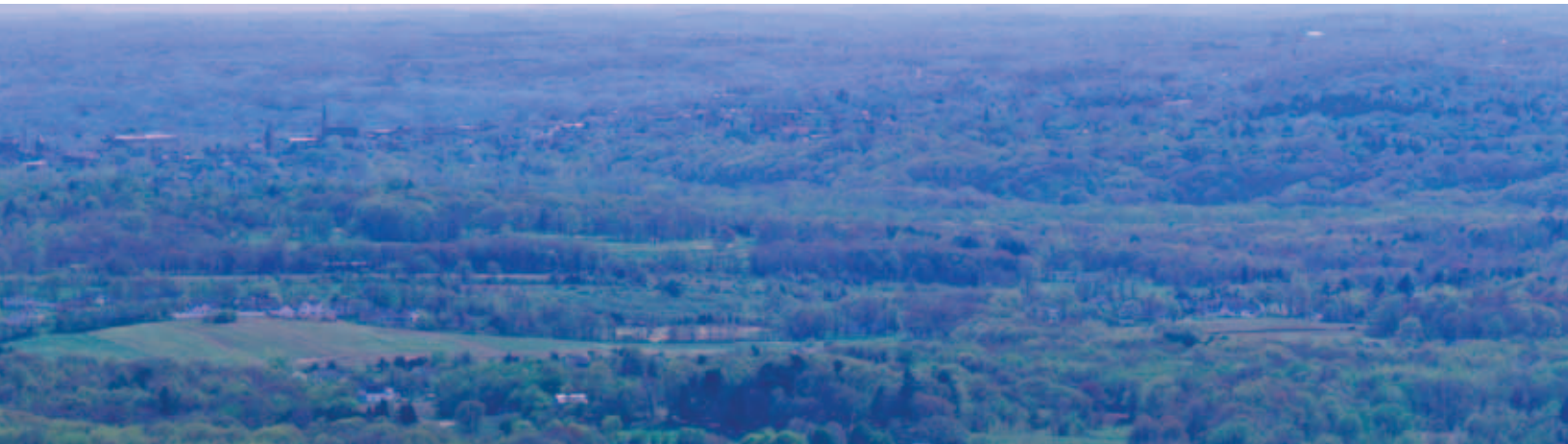
ACKNOWLEDGEMENTS

BioMap2 is the result of a collaborative effort pulled together by many people over a 15-month time frame. Special thanks go to Mary Griffin, Commissioner of the Department of Fish & Game, for her strong support and encouragement throughout, and to Wayne Klockner, State Director of The Nature Conservancy's Massachusetts Program, for his steadfast commitment to The Conservancy's partnership in the project. Thanks also to Loring Schwarz and Jack Buckley for helping to initiate the project.

Responsibility for actually producing *BioMap2* fell primarily to Henry Woolsey at the Natural Heritage & Endangered Species Program and Andy Finton at The Nature Conservancy. James DeNormandie, contracted through Mass Audubon, was pivotal as *BioMap2* Project Coordinator, accomplishing myriad tasks simultaneously. Rounding out the core project team and overseeing important components of project design, analysis, and documentation were Jessica Dyson (TNC GIS Manager), Sarah Haggerty (Natural Heritage Information Manager), and Glenn Motzkin (Landscape Ecologist).

In a large project such as this, there are countless people and organizations to thank for their crucial labor as well as critical advice. Contractors to thank include: Jeanne Anderson (coastal analyses); Claire Corcoran (writing & editing); Charley Eiseman (wetland field checking); Joanna Grand (freshwater fish analyses); Rob Levine (graphic design); Ann Prince (copyediting); Dan Zeh (GIS editing); and Brad Compton, Kevin McGarigal, and Scott Jackson, at the UMass, Amherst Department of Environmental Conservation (Ecological Integrity analyses). Special thanks are due to all the Natural Heritage Program staff who provided critical input at various stages of the project, especially Kristin Black, Tara Boswell, Chris Buelow, Bryan Connolly, Lori Erb, Marea Gabriel, Jennifer Garrett, Lynn Harper, Mike Jones, Jake Kubel, Lisa MacGillivray, Carolyn Mostello, Mike Nelson, Tim Simmons, and Pat Swain. Many other staff at the Division of Fisheries and Wildlife contributed to important components of the project; namely Bill Byrne (photographs), Tom French, Leanda Fontaine, Steve Hurley, Alicia Norris, Dana Ohman, John O'Leary, Tom O'Shea, Todd Richards, Caleb Slater, and Mark Tisa, as well as Hector Galbraith, DFW partner in climate change vulnerability assessment. We also want to thank the DFW Fisheries section for the use of their fish database and their time in analyzing and mapping aquatic habitat. Data provided by Brad Chase and Phil Brady of the Division of Marine Fisheries were used to assess core habitat for anadromous fish species. Other Department of Fish & Game staff, Dan Koch and Kevin Robicheau, were instrumental in creating the project's web components. A number of Nature Conservancy staff provided expertise, data, and analysis: Mark Anderson, Charles Ferree, Arlene Olivero, and especially Alison Bowden (migratory fish analyses). Lastly, we want to thank the many attendees at our external review meeting for their insights.

The Commonwealth of Massachusetts funded the project largely from capital bond funds and from the Natural Heritage & Endangered Species Fund. The Department of Fish and Game also gratefully acknowledges a critical grant received from the Open Space Institute, with support from the Doris Duke Charitable Foundation. The Nature Conservancy is especially grateful for support from The Ackerman Conservation Fund, Toward Sustainability Foundation, and Elinor M. and Joel L. Siner. Supplementary outreach support was provided by the Massachusetts Outdoor Heritage Foundation.



Dear Friend of the Environment,

Massachusetts is graced with a rich natural heritage including expansive forests, diverse wetlands, vital rivers, and an extensive coastline—all of which support a wide variety of plants and animals as well as the health and well-being of the people of Massachusetts. In 2001 and 2003, the Natural Heritage & Endangered Species Program produced *BioMap* and *Living Waters*, innovative biodiversity conservation plans designed to guide the protection of these natural resources.

Since that time, the Commonwealth and many partners have used these plans to make great strides in conserving critical lands and protecting the crucial resources upon which we all rely. We have greatly benefited in recent years from Governor Patrick's strong support for land conservation; however, much remains to be done to safeguard our state's natural heritage. To the list of environmental stresses, we now face concerns and uncertainty about the effects of accelerated climate change on our wildlife species and habitats. It is therefore especially important to keep focused on robust and forward-looking conservation goals.

We are very enthusiastic to present ***BioMap2***, an enhanced and comprehensive biodiversity conservation plan for Massachusetts that updates and broadens the biological and conceptual scope of the original plans. Based on the foundation of our previous work, *BioMap2* is built on cutting-edge conservation biology principles, rigorous data collection, and sophisticated GIS analyses. We have also incorporated climate change adaptation strategies in our biodiversity conservation map.

This new science-based plan, although ambitious, is at the scale truly needed to achieve effective conservation and build ecological resilience for generations to come. Please join us in helping to protect the full breadth of the Commonwealth's natural heritage.

MARY GRIFFIN, ***Commissioner***
DEPARTMENT OF FISH & GAME
COMMONWEALTH OF MASSACHUSETTS

WAYNE KLOCKNER, ***State Director***
MASSACHUSETTS PROGRAM
THE NATURE CONSERVANCY

EXECUTIVE SUMMARY

The Massachusetts Department of Fish & Game's Natural Heritage & Endangered Species Program (NHESP) and The Nature Conservancy's Massachusetts Program developed *BioMap2* to protect the state's biodiversity in the context of projected effects of climate change.

BioMap2 combines NHESP's 30 years of rigorously documented rare species and natural community data with spatial data identifying wildlife species and habitats that were the focus of the Division of Fisheries and Wildlife's 2005 State Wildlife Action Plan (SWAP). *BioMap2* also integrates The Nature Conservancy's assessment of large, well-connected, and intact ecosystems and landscapes across the Commonwealth, incorporating concepts of ecosystem resilience to address anticipated climate change impacts.

Core Habitat consists of 1,242,000 acres that are critical for the long-term persistence of rare species and other Species of Conservation Concern, as well as a wide diversity of natural communities and intact ecosystems across the Commonwealth. Core Habitat includes

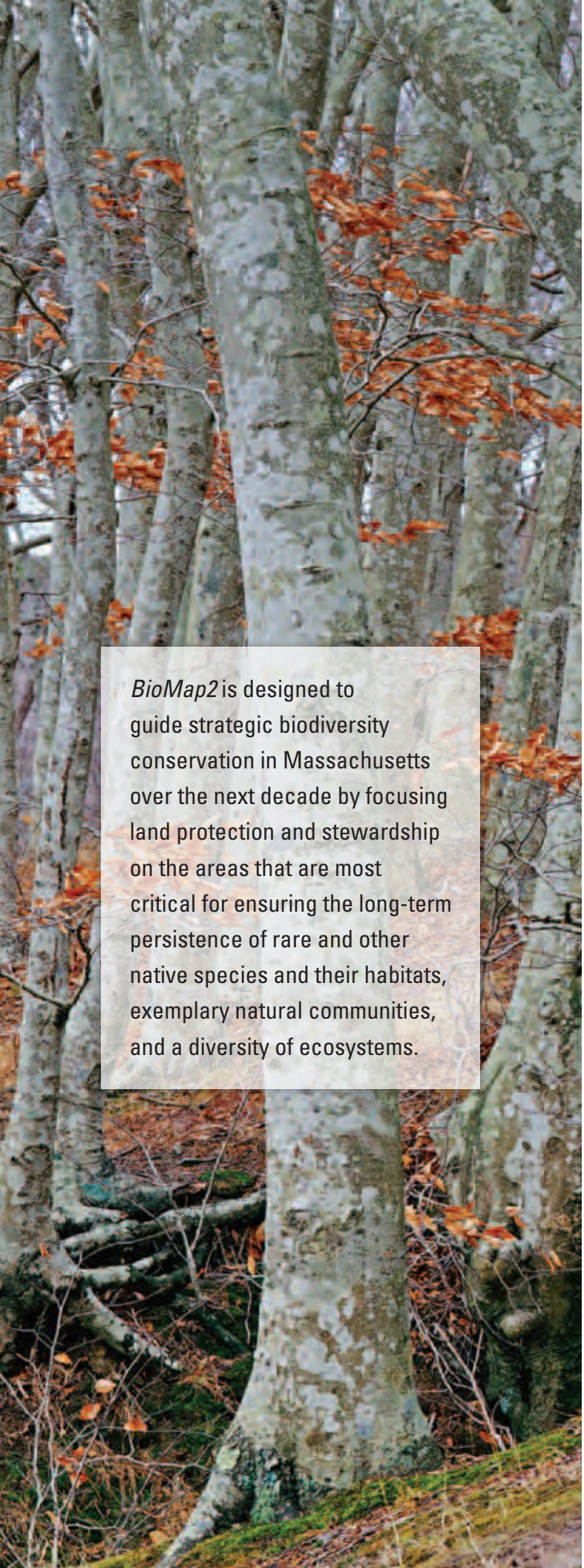
- Habitats for rare, vulnerable, or uncommon mammal, bird, reptile, amphibian, fish, invertebrate, and plant species;
- Priority Natural Communities;
- High-quality wetland, vernal pool, aquatic, and coastal habitats; and
- Intact forest ecosystems.

Critical Natural Landscape (CNL) consists of 1,783,000 acres complementing Core Habitat, including large natural Landscape Blocks that provide habitat for wide-ranging native species, support intact ecological processes, maintain connectivity among habitats, and enhance ecological resilience; and includes buffering uplands around coastal, wetland and aquatic Core Habitats to help ensure their long-term integrity. CNL, which may overlap with Core Habitat includes

- The largest Landscape Blocks in each of 8 ecoregions; and
- Adjacent uplands that buffer wetland, aquatic, and coastal habitats.

	Total Acres	*Percent of State*	*BioMap2 Acres Protected*
Core Habitat	1,242,000	24%	559,000
Critical Natural Landscape	1,783,000	34%	778,000
BioMap2 Total *(with overlap)*	2,092,000	40%	861,000

Protection and stewardship of ***BioMap2* Core Habitat** and **Critical Natural Landscape** is essential to safeguard the diversity of species and their habitats, intact ecosystems, and resilient natural landscapes across Massachusetts.



BioMap2 is designed to guide strategic biodiversity conservation in Massachusetts over the next decade by focusing land protection and stewardship on the areas that are most critical for ensuring the long-term persistence of rare and other native species and their habitats, exemplary natural communities, and a diversity of ecosystems.

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WEB RESOURCES OF *BIOMAP2*

To download the *BioMap2* Summary Report and explore an interactive web-map of *BioMap2*, visit the *BioMap2* website at www.nhesp.org, under the Land Protection and Planning tab. For a more complete treatment of *BioMap2* mapping approaches and results, please refer to the *BioMap2* Technical Report, also available for download at the above web address.

CHAPTER 1

A Conservation Challenge for the Commonwealth

Ridge top natural community, Warren, MA

A RICH YET THREATENED HERITAGE OF SPECIES AND HABITATS

Although Massachusetts is a small state, it is extremely varied. From the beaches and salt marshes of Cape Cod, to the rich habitats of the Connecticut River Valley, to the forests and ridgetops of the Taconic Mountains, the Commonwealth supports a remarkable diversity of plant and animal species and natural ecosystems representative of many of New England's distinct regions. These ecosystems serve critical ecological and societal functions by purifying water, cleaning the air, providing a wide range of food and forest products, and enhancing the quality of life in Massachusetts.

At the same time, native species and ecosystems across the Commonwealth face unprecedented threats. Development, particularly residential development, continues to eliminate and fragment important habitats. Traffic volume has increased in Massachusetts, causing a rise in mortality for amphibians and reptiles. New and established invasive species continue to displace native plants and animals. Meanwhile, the emerging repercussions of climate change threaten complete disruption of the ecological conditions and processes our ecosystems and species depend on. In light of these threats, there is a critical need to protect the state's biodiversity and ensure that ecosystems across Massachusetts remain viable.

BIOMAP2: CONSERVING THE BIODIVERSITY OF MASSACHUSETTS IN A CHANGING WORLD

BioMap2 provides a framework for protection and stewardship of those lands and waters that are most important for conserving biological diversity in Massachusetts. It was created with an objective set of analyses to identify species habitats and intact ecosystems across the state that are critical for biodiversity and that, if protected, will enhance ecological resilience to climate change and other threats.

Melsheimer's Sack Bearer *(Cicinnus melscheimeri),* Threatened

Common Loon *(Gavia immer),* Special Concern

NATURAL HERITAGE & ENDANGERED SPECIES PROGRAM (NHESP)

Over 30 years ago, The Nature Conservancy helped launch the Massachusetts NHESP as part of its push to establish natural heritage programs in all 50 states. Since its establishment, the NHESP has been working to ensure conservation of the Commonwealth's native biodiversity, especially the species and natural communities most in need of protection and stewardship. The elements of biodiversity of particular focus for the program are the 435 native plant and animal species listed under the **Massachusetts Endangered Species Act** (MESA) and the 108 types of natural communities currently described within Massachusetts and tracked by the Natural Heritage Program. Information on these species and natural communities is stored in a central database currently containing over 19,000 geographically referenced records. Natural Heritage data form a key component of *BioMap2*.

THE NATURE CONSERVANCY, MASSACHUSETTS PROGRAM (TNC)

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The Nature Conservancy is a leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. The Nature Conservancy's mission ***to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive*** is carried out in all 50 US states and in more than 30 other countries around the world. Since its inception in 1951, the Conservancy has maintained a science-based approach to conservation. The Nature Conservancy's Massachusetts Program has focused on analyses and conservation of globally important forests, rivers, wetlands, and coastal systems; these analyses were incorporated into *BioMap2*, strongly complementing the data developed by the Natural Heritage & Endangered Species Program.

With similar missions, goals, and science-based approaches to biological conservation, the Natural Heritage & Endangered Species Program and The Nature Conservancy are natural partners to develop *BioMap2*.

For *BioMap2*, the Department of Fish and Game and the Division of Fisheries and Wildlife—primarily through the Natural Heritage & Endangered Species Program (NHESP)—worked closely with The Nature Conservancy to build on the success of the initial *BioMap* and *Living Waters* biodiversity conservation plans, and to implement the State Wildlife Action Plan. The result is an enhanced, updated, and more comprehensive *BioMap* using innovative GIS capabilities, improved biodiversity data, and increased biological expertise. *BioMap2* is an updated conservation blueprint based on the habitat needs of the state's rare species and additional wildlife Species of Conservation Concern, and a broad representation of important ecosystems.

Since the publication of the first *BioMap*, scientific knowledge of the status, trends, and distribution of the state's biodiversity has greatly increased. NHESP staff have discovered new species in the state, rediscovered species thought to have long been extirpated, and described new natural communities. In addition, knowledge of the dynamic nature of ecosystems has evolved, with new analyses available that identify outstanding examples of these complex and critically important resources. Recent studies have also contributed to a growing understanding of the vulnerability of diverse habitats to climate change.

A population of the Appalachian Coronet *(Hadena ectypa)*, a Species of Conservation Concern, was recently discovered in Massachusetts by NHESP staff. This is the first population recorded in New England.

The largest population of the globally rare-Endangered orchid Nodding Pogonia *(Triphora trianthophora)* in Berkshire County was discovered in 2008; this population, comprising about 1,000 orchids, represents one of the most significant botanical finds in recent years and is one of only five known statewide.

MASSACHUSETTS' PRIOR BIODIVERSITY CONSERVATION PLANS

When the original *BioMap* was released in 2001, it was the first conservation plan for Massachusetts to present a map of the areas needed to protect the state's breadth of biological diversity. However, the need to develop a statewide plan for proposed open space dates back over 80 years, as evidenced by the 1929 Map of Existing and Proposed Open Spaces.

This map was produced in 1929 by a Governor's Committee on Needs and Uses of Open Spaces after a four-year effort. This early conservation planning project is revealing not only in that it highlights subsequent land protection successes, but also that the job is unfinished. Although the focus of this planning effort was on open space rather than biodiversity, it does highlight a number of areas of great current ecological importance that are included in *BioMap2*.

The NHESP's original *BioMap* delineated Core Habitats, representing the most critical terrestrial rare species habitats and priority natural communities, as well as Supporting Natural Landscapes—large, minimally fragmented areas abutting, and intended to help safeguard, Core Habitats. In 2003 Natural Heritage produced a companion plan, *Living Waters*, which focused on freshwater biodiversity by identifying *Living Waters* Core Habitats and Critical Supporting Watersheds. In 2004, Natural Heritage produced and distributed to each town a customized town map and descriptive report based on both plans.

The *BioMap* and *Living Waters* plans were widely accepted by the conservation community and were immediately used in land protection work across Massachusetts. For example, several funding programs for land acquisition projects quickly incorporated the *BioMap* into their ranking prioritization systems. In addition, numerous towns incorporated it into their Open Space Plans, and it is used in natural resource planning by state agencies, land trusts, and nonprofit organizations. Close to 72,000 acres identified as Core Habitat in 2001 have since been protected, as well as 45,000 acres of Supporting Natural Landscape. Combined, this represents nearly 70 percent of all lands protected by all entities since 2001.

THE NEED FOR AN UPDATED AND ENHANCED *BIOMAP*

Massachusetts' original *BioMap* plan was based on data collected prior to 2001. Since that time, more than 4,000 new and updated records have been added to the Natural Heritage & Endangered Species Program's database. During the past decade, enhanced understanding of species requirements has also led to improved habitat mapping for state-listed species by NHESP. In addition, researchers at The Nature Conservancy and UMass Amherst have developed spatial analyses to define resilient ecosystems, applying the latest understanding of how to best ensure that natural systems are able to respond to changing climate.

There have also been significant changes in land use, development, and other threats to native biodiversity in recent years. In 2009, the Massachusetts Audubon Society released the 4th edition of *Losing Ground*, which shows that, outside of developed areas, over half of the remainder of Massachusetts is now either in the Sprawl Frontier or Sprawl Danger Zone. In 2005, the Massachusetts Division of Fisheries and Wildlife completed a comprehensive **State Wildlife Action Plan** (SWAP) documenting the status of Massachusetts wildlife and providing recommendations to help guide wildlife conservation decision-making. SWAP includes all the wildlife species listed under the Massachusetts Endangered Species Act (MESA), as well as more than 80 species that need conservation attention but do not meet the requirements for inclusion under the state Endangered Species Act. The SWAP document is organized around habitat types in need of conservation within the Commonwealth. While the original *BioMap* focused primarily on rare species protected under MESA, *BioMap2* also addresses other Species of Conservation Concern, their habitats, and the ecosystems that support them to create a spatial representation of most of the elements of SWAP.

BIOMAP2: UPDATED AND ENHANCED

In *BioMap2*, all information has been updated to reflect

- Improved GIS spatial data on land development and land use changes, as well as the nearly 170,000 acres of land conserved in Massachusetts since 2001;
- Over 4,000 new observations and updated data on species and natural communities now in the Natural Heritage Program's database;
- A better understanding of the geographic extent and types of suitable habitat needed to support many of our MESA-listed species; and
- Integration of the analyses of the terrestrial species and habitats included in *BioMap* with the freshwater aquatic resources included in the original *Living Waters* plan.

The taxonomic and ecological scope of *BioMap2* has been enhanced to

- Encompass other vulnerable fish and wildlife species and the habitats identified in Massachusetts' State Wildlife Action Plan;
- Use state-of-the art models of Ecological Integrity to identify intact upland, wetland, riverine, and coastal ecosystems and landscapes across the state; and
- Include ecologically resistant and resilient ecosystems to better address anticipated effects of climate change.

BIOMAP2: ONE PLAN, TWO COMPONENTS

BioMap2 identifies two complementary spatial layers, Core Habitat and Critical Natural Landscape. **Core Habitat** identifies key areas that are critical for the long-term persistence of rare species and other Species of Conservation Concern, as well as a wide diversity of natural communities and intact ecosystems across the Commonwealth. Protection of Core Habitats will contribute to the conservation of specific elements of biodiversity.

Critical Natural Landscape identifies large natural Landscape Blocks that are minimally impacted by development. If protected, these areas will provide habitat for wide-ranging native species, support intact ecological processes, maintain connectivity among habitats, and enhance ecological resilience to natural and anthropogenic disturbances in a rapidly changing world. Areas delineated as Critical Natural Landscape also include buffering upland around wetland, coastal, and aquatic Core Habitats to help ensure their long-term integrity.

The long-term persistence of Massachusetts biological resources requires a determined commitment to land and water conservation. Protection and stewardship of both Critical Natural Landscapes and Core Habitats are needed to realize the biodiversity conservation vision of *BioMap2*.

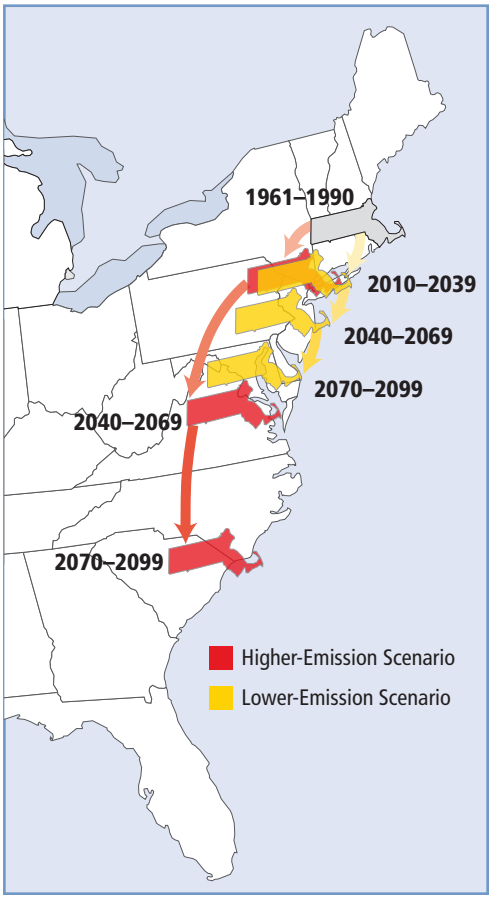
CHAPTER 2
Ecological Resistance and Resilience: Addressing Threats to Biodiversity

BioMap2 identifies critical land protection and stewardship priorities to help conserve the biodiversity of Massachusetts over the long term. Habitat loss and fragmentation are well understood as significant threats to biodiversity; in recent years, understanding of climate change and its potential to dramatically affect biodiversity has increased substantially. In addition to habitat loss, fragmentation, and climate change, ecosystems and organisms are threatened by invasive species, pollution, and altered ecosystem processes. *BioMap2* is designed to inform strategic land protection to enhance overall ecological resistance and resilience, critical components of biodiversity conservation in the face of these perils.

CLIMATE CHANGE IN MASSACHUSETTS

There is abundant evidence that the earth is experiencing rapid climate change, and that anthropogenic emissions of greenhouse gases are playing a major role. Temperatures will continue to rise as long as emissions are not reduced. Since 1900, global mean temperatures have risen by about 1.3°F and are now higher than they have been for at least the last 600 years. Some specific climate changes anticipated in Massachusetts include

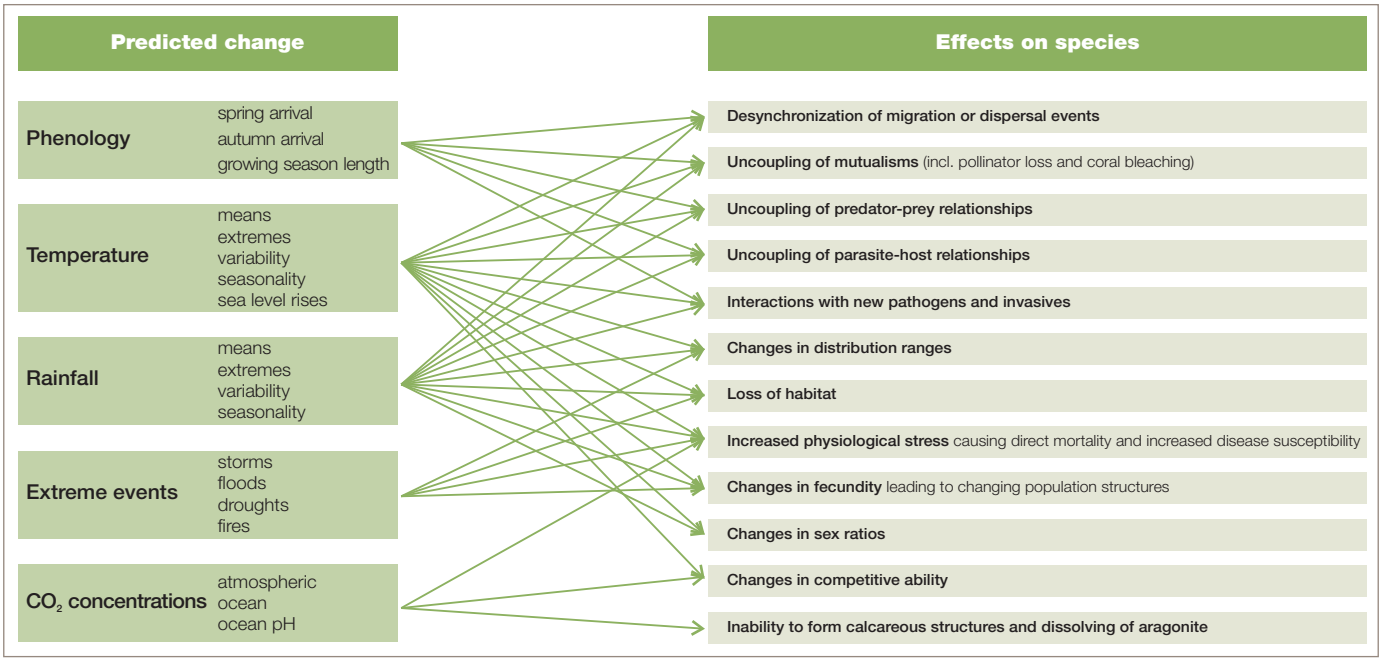
- **Temperature.** Average temperatures across the Northeast have risen more than 1.5°F since 1970, with winters changing most rapidly, warming 4°F between 1970 and 2000. Average temperatures across Massachusetts are projected to rise by as much as 6°F to 14°F above historical levels by the late 21st century, depending on rates of carbon emissions in the coming decades.
- **Precipitation, drought, and winter snow.** Heavy rainfall events have increased measurably across the Northeast in recent decades, and the frequency and severity of such events is expected to rise further, likely resulting in more frequent flooding. Winter precipitation is projected to increase by 20 to 30 percent, with a shift toward increased rain and substantially decreased snow. At the same time, an increased frequency of short-term summer droughts is expected.
- **Sea-level rise.** Sea level is projected to rise by up to several feet by the end of the century, leading to increases in the extent and frequency of coastal flooding and erosion.



Average summer heat indices projected under two emissions scenarios
(Used by permission of Union of Concerned Scientists, 2007).

ECOLOGICAL RESPONSE AND VULNERABILITY

Although there is considerable uncertainty in how species and ecosystems will respond to such climatic shifts, global climate change is already having significant effects on biodiversity. As with past climatic shifts, some species will adapt and thrive under altered climate regimes, whereas others will seriously decline. The interaction between predicted changes and species response is complex.



The complex interactions between projected climate changes and their effects on species.
Used by permission of Foden et al. 2008.

In 2010 the Manomet Center for Conservation Sciences and the Massachusetts Division of Fisheries and Wildlife released an assessment of the relative vulnerability of Massachusetts habitats to the effects of climate change. Systems typical of northern latitudes, such as spruce-fir forests and swamps found in the higher elevations of western Massachusetts, are particularly susceptible. Another class of vulnerable ecosystems occurs along the coast, where sea-level rise may leave systems such as intertidal flats and brackish marshes unable to adapt.

Rising sea levels and greater storm surges will threaten coastal resources.

CLIMATE ADAPTATION AND ECOLOGICAL RESILIENCE

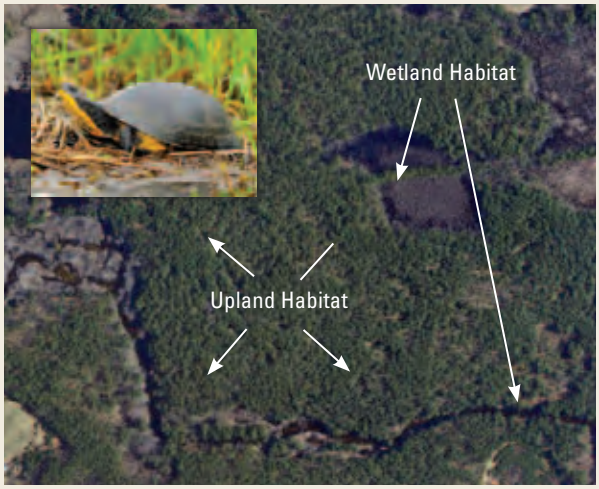
A variety of emerging strategies, collectively termed Climate Change Adaptation, are designed to help ecosystems and populations cope with the adverse impacts of climate change. *BioMap2* incorporates a suite of these strategies to promote **resistance** and **resilience** of plant and animal populations and ecosystems, and to assist anticipated **transformations** caused by climate change and other stressors.

The strategies adopted for *BioMap2* are critical components of a comprehensive strategy needed to address climate change. Ultimately, *BioMap2* should be combined with on-the-ground stewardship and restoration efforts, such as dam removal, forest management, and rare species habitat management, providing a comprehensive approach to biodiversity conservation in the face of climate change. This set of strategies must complement international, national, and regional emission reductions in order to reduce the threat of climate change to species and ecosystems.

BioMap2 uses the following strategies to impart resistance and resilience to species habitats, natural communities, and ecosystems.

- **Prioritizes habitats, natural communities, and ecosystems of sufficient size.** Large wetlands, forests, river networks, and other intact ecosystems generally support larger populations of native species, a greater number of species, and more intact natural processes than small, isolated examples. Large examples are also likely to help plants and animals survive extreme conditions expected under climate change. *BioMap2* includes the largest examples of high-quality forest and wetland ecosystems and intact landscapes, as well as extensive species habitats and intact river networks.
- **Selects habitats, natural communities, and ecosystems that support ecological processes.** Ecological processes sustain the diversity of species within ecosystems. Examples include natural disturbances, like windstorms in forests that result in a mosaic of forest ages, each of which supports a different suite of plants and animals. Similarly, intact rivers support functional hydrological regimes, such as flooding in the spring, that support the diversity of fish and other species found in a healthy river. *BioMap2* identifies ecosystems with the best chance of maintaining ecological processes over long time periods; these resilient habitats are most likely to recover from ecological processes that are altered by climate change.
- **Builds connectivity into habitats and ecosystems.** Connectivity is essential to support the long-term persistence of populations of both rare and common species. Local connectivity provides opportunities for individual animals to move through the landscape. For instance, wood frogs and blue-spotted salamanders need to move between springtime vernal pool habitats where they breed and upland forest habitats where they feed in summer and overwinter. *BioMap2* maximizes local connectivity in forest, wetland, vernal pool, river, and rare species habitats. Regional connectivity allows long-distance dispersal, which helps to maintain vital populations. The intact landscapes of *BioMap2* support regional connectivity, including several cross-state areas of critical importance.
- **Represents a diversity of species, natural communities, ecosystems, and ecological settings.** To ensure that the network of protected lands represents the full suite of species, both currently and into the future, *BioMap2* includes rare and common species, natural communities, and intact ecosystems across the state. *BioMap2* also includes ecosystems across the full range of ecoregions and ecological settings; such diverse physical settings support unique assemblages of plants and animals and serve as 'coarse filters' for protecting biological diversity. As species shift over time in the context of changing climate, a diversity of physical settings and ecosystems will be available to support biodiversity.

CLIMATE CHANGE ADAPTATION APPROACHES



Resistance

The ability of an ecosystem or population to persist and to ***remain relatively stable in response to climate change and other stressors***. The concept of resistance is incorporated into *BioMap2* for species like the Threatened Blanding's Turtle by identifying extensive habitat patches that support large populations, allow movement from wetlands to uplands, and allow movement among wetlands, all of which impart resistance to populations in the face of projected summer droughts, spring flooding, and other threats.

Resilience

The ability of an ecosystem or population to ***recover from the impacts of climate change and other stressors***. In many cases, ecosystems will change in species composition and structure in response to climate change; increased resilience supports an ecosystem's ability to adapt to climate change and maintain ecological function. For example, wetlands will likely experience changes in temperature and hydrological regime (i.e., the timing and amount of water) due to projected climate changes, resulting in changes in plant and animal composition. By selecting large, unfragmented wetlands that are well buffered, *BioMap2* prioritizes wetlands that are best able to maintain function and support native biodiversity.

Transformation

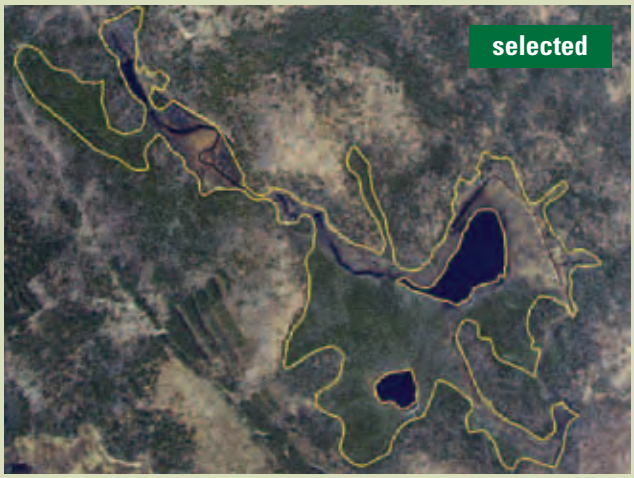
The transition of an ecosystem or population ***to another ecological state in response to climate change and other stressors***. *BioMap2*, recognizing such transformations are particularly likely along the coast, identifies low-lying, intact uplands adjacent to salt marshes to allow the migration of estuarine ecosystems up-slope in the context of rising sea levels.

Early spring along the East Branch of the Swift River, Petersham.

- **Protects multiple examples of each species habitat, natural community, and ecosystem.** Simply put, by selecting multiple examples of each species habitat, natural community, ecosystem, and landscape, *BioMap2* reduces the risk of losing critical elements of the biodiversity of Massachusetts. The extreme weather events projected under climate change, and the uncertainties of ecosystem response, will likely mean that some populations will not persist, and some ecosystems will cease to function as they have in the past. By selecting multiple examples and distributing them geographically and among different settings, *BioMap2* increases the likelihood that one or more examples will survive into the future.
- **Minimizes non-climate stressors to species and ecosystems.** Limiting other stressors is one of the most important strategies to impart resistance and resilience to species and ecosystems. *BioMap2* identifies those habitats least impacted by roads and traffic, development, dams, water withdrawals, and other sources of stress, which also have the least likelihood of related stressors such as edge effects, invasive species, and alterations to water quantity and quality. Despite efforts to select the least-altered habitats, these areas are not pristine, and stewardship to reduce additional stressors is often required.

BioMap2 wetland ecosystem selection a) avoids wetlands disturbed by roads and development, and b) selects intact wetlands with minimal fragmentation.

a



b

Protection of the lands identified in *BioMap2* will not be sufficient, in and of itself, to ensure the persistence of the biodiversity of Massachusetts. Other adaptive strategies to climate change that complement *BioMap2* include

- **Management and restoration of populations, habitats, and ecosystems.** Ecological restoration of degraded habitats—to restore composition, structure, and function—enhances resistance and resilience. Stewardship needs include the control of invasive species, forest management to enhance young forest for declining species, and prescribed burning to increase habitat diversity and reduce wildfire hazard. The restoration of aquatic connectivity and flow regimes may benefit from dam removal and improvement of road stream-crossings. In some cases, translocation or reintroduction of imperiled species may be warranted.
- **Adaptive management of species and ecosystems.** Although important for all conservation actions, measuring and monitoring the results of climate change adaptation strategies, and learning from these analyses, are especially important due to the uncertainties of future climate changes and impacts.

Habitat management using prescribed fire.

NON-CLIMATE THREATS TO BIODIVERSITY

Beyond climate change, there are numerous threats to the long-term viability of Massachusetts plant and animal populations and functional ecosystems, resulting in a decrease in abundance and reduced geographic distribution for many species. A few critical stressors strongly impact a great number of species and ecosystems across the Commonwealth.

- **Habitat loss.** The greatest contributor to the loss of critical habitats and intact ecosystems in Massachusetts has been the direct destruction of habitat by residential, commercial, and industrial development. Over 1.1 million acres (21%) of Massachusetts are developed, and extensive areas of additional habitats surrounding development are degraded as invasive species, pollution, noise, nighttime lights, and other factors radiate out from development and penetrate into the surrounding landscape. Impervious surfaces, and associated runoff into rivers and streams, degrade aquatic ecosystems. Low-lying lands along the coast and river valleys, which often support a variety of rare species and important natural communities, continue to experience particularly high levels of development. In recent decades, the loss of habitat to development has been compounded by the ever greater size of each residential unit.

Habitat loss caused by residential development.

- **Habitat fragmentation.** Habitat fragmentation results from construction of roads, associated residential and commercial development, dams, and other infrastructure that breaks large forests, wetlands, and rivers into smaller habitat blocks, isolates populations, and interrupts movement. Animals that move for migration, dispersal, and daily needs are frequently killed by automobiles. Roads also alter the behavior of animals because many avoid or do not cross roads. Populations of migratory and resident freshwater fish have been severely impacted by dams and road stream-crossings. Roads and railroads separating river channels from adjoining floodplain wetlands are also common.

Eastern Spadefoot Toad *(Scaphiopus holbrookii),* Threatened

  Fragmentation also reduces interior habitat and increases edge effects on species habitats and ecosystems. Edge effects include the spread of invasive plants into native habitats from roadways; predation of forest-nesting birds by house cats, skunks, raccoons, and other animals typical of disturbed areas; and alteration of microclimates by increased sun and wind.

Roads often divide forest, wetland, and river habitat.

Dams and other structures fragment river habitat.

- **Invasive species.** The introduction and widespread establishment of invasive plants, animals, insects, and diseases has led to degradation of Massachusetts ecosystems and rare species populations. Non-native forest insects have few or no natural predators in their new environment, and native tree species may be highly susceptible to non-native pathogens. For instance, chestnut blight has essentially removed this once-dominant species from our forests, with cascading impacts to the many species that once fed on its abundant nuts, including the Black Bear and Wild Turkey. Hemlock Woolly Adelgid and beech bark disease have also had tremendous impacts on forest ecosystems, and new invasions such as the Asian Longhorned Beetle lurk on the horizon. An invasive plant, Common Reed has naturalized in wetlands across the state, altering wetland hydrology and reducing native wetland plant populations. White-tailed deer, though native, have high populations in some areas, leading to the decimation of forest wildflowers and tree seedlings.

Periodic inundation of floodplain forest is an important ecological process.

- **Air and water pollution.** Freshwater, estuarine, and terrestrial ecosystems are frequently degraded by air and water pollutants. Point-source pollution from specific locations such as power plants and sewage pipes add toxic chemicals and heated water to fresh and coastal waterways, degrading ecosystems and reducing or eliminating sensitive plants and animals. Non-point source pollution from diffuse sources, including sediment, fertilizers, pesticides, livestock waste, road salt, oil, and heavy metals have even more widespread impacts.
- **Alteration of ecological processes.** Many critical habitats are maintained by periodic disturbances such as flooding, fire, frost, ice- and wind-storms, and other processes. Habitat loss, habitat fragmentation, water impoundment, channelization of rivers, water withdrawals, fire suppression, removal of predators, and other activities reduce the dynamic nature of terrestrial and aquatic ecosystems, undermining these critical processes. For example, the timing, magnitude, and frequency of water flowing through rivers is greatly altered by dams, dikes, and water withdrawals, and species dependent on these processes are, in turn, affected.

How *BioMap2* addresses these threats. *BioMap2* directly addresses the significant threat of continued habitat loss by identifying statewide conservation target areas that, if protected, will minimize further losses to native biodiversity. *BioMap2* also minimizes potential fragmentation effects by selecting habitats that are the least fragmented and have the greatest potential to maintain ecological processes. For example, *BioMap2* prioritizes forest interior habitats that are unfragmented by roads, and river networks that have few dams or road stream-crossings. In addition, *BioMap2* prioritizes ecosystems that are buffered from roads and development, reducing the likelihood of invasive species establishment and local pollution inputs.

BioMap2 is a scientific conservation plan based on principles of conservation biology. Applied to land protection, *BioMap2* will enhance the resilience and resistance of species and ecosystems to an array of stressors. Strategic land protection, along with scientifically based ecological restoration and stewardship, will mitigate a broad spectrum of threats to the biodiversity of Massachusetts.

CHAPTER 3
Building a Better *BioMap*

The goal of the team behind *BioMap2* was to build a tool to guide land protection and stewardship for biodiversity conservation in Massachusetts. To do so, it was first necessary to identify specific conservation objectives and to determine those aspects of biodiversity that should serve as conservation targets. The creators of *BioMap2* intentionally adopted broad conservation objectives to prioritize areas that are critical for ensuring the long-term persistence and functioning of rare and common native species, uncommon natural communities and more common ecosystems, and large, relatively intact landscapes and associated ecosystem processes. This comprehensive approach is critical both for conserving current biodiversity and for preparing for substantial but largely unknown changes in the coming decades resulting from climate change and other stressors. Such an approach is also needed to help guide individuals, agencies, and organizations concerned with varied aspects of biodiversity and wildlife habitat conservation.

Early Hairstreak *(Erora laeta)*, Threatened

Eastern Ratsnake *(Pantherophis alleghaniensis)*, Endangered

For a more complete treatment of mapping approaches used in *BioMap2*, please refer to the *BioMap2* Technical Report, available by download from the following website, www.nhesp.org.

BioMap2 employs a combination of fine-filter and coarse-filter approaches. The fine-filter approach targets the conservation needs of individual species, especially those that are currently rare or uncommon, as well as those that may be threatened in the coming decades.

The coarse-filter approach focuses on conservation of the full range of natural communities, intact ecosystems, and unbroken landscapes. Conservation of these systems will ensure that the vast majority of species, both rare and common, are effectively protected and is critical to maintain natural ecosystem processes (e.g., natural disturbances such as wind and fire, decomposition, nutrient cycling, etc.). Additionally, identifying ecosystems representing a diversity of underlying physical settings (e.g., elevation, bedrock, etc.) is important because patterns of species distribution, community occurrence, and ecosystem process are strongly influenced by such factors. Conservation of the full range of environmental settings on the landscape is particularly important for accommodating anticipated shifts in species distribution in response to climate change.

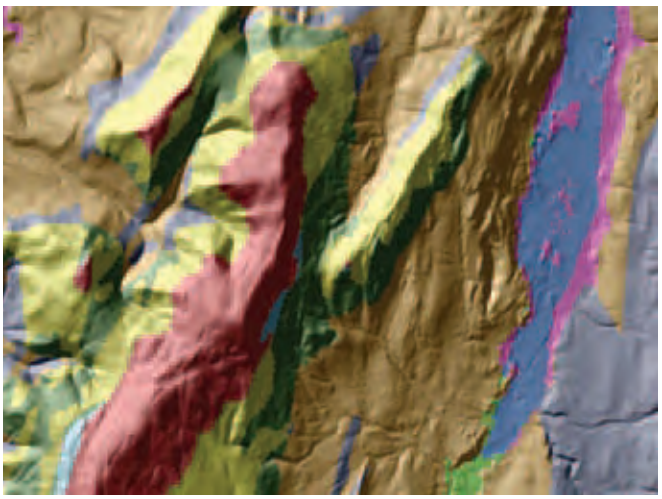
IDENTIFY, MAP, AND BALANCE CONSERVATION TARGETS

In *BioMap2*, each conservation target falls into one of two complementary categories, **Core Habitat** and **Critical Natural Landscape**. Core Habitat identifies key areas to ensure the long-term persistence of rare species, other Species of Conservation Concern, and exemplary natural communities and intact ecosystems across the Commonwealth. Critical Natural Landscape identifies large natural landscape blocks that are minimally impacted by development, as well as buffers around some Core Habitats, both of which enhance resilience.

The selection of Core Habitats and Critical Natural Landscapes for *BioMap2* followed a sequence of methods that involved identifying, mapping, and balancing the representation of each conservation target. First, the species, natural community, ecosystem, and landscape targets that make up *BioMap2* were identified. Each was then carefully mapped and delineated using innovative techniques to highlight those areas least influenced by development, and thus most likely to support biodiversity over time. These components were then evaluated to ensure that they adequately represent a diversity of settings and geographic distribution across the state.

PROTECTING THE STAGE: ECOLOGICAL SETTINGS AND ECOREGIONS

Climate plays an important role in determining which species may occur in a region such as the Northeast. However, within the region, species distributions are strongly influenced by features such as local geology and topography because these factors affect the availability of water, nutrients, and other resources needed by plants and animals. It is important to incorporate such variation in ecological settings into long-term biodiversity conservation because these ecological settings will endure over time even as species shift in response to climate change. From this perspective, conserving an ecological setting is analogous to conserving an ecological stage, knowing that the individual ecological actors will change with time. Protecting the stage will help to conserve varied habitats and to retain functioning ecosystems in place, even though the exact species composition may change.



Mount Greylock
The distribution of ecological settings defined by different combinations of elevation and geology. These settings determine the distribution of species and natural communities.

BioMap2 used two approaches to represent ecosystems in different ecological settings. The most intact wetlands were selected to ensure that they represent the diversity of ecological settings across Massachusetts based on unique combinations of the underlying geology and elevation. For instance, wetlands were selected on sandy soils at low elevations along the coast, at moderate elevations in the marble valleys of western Massachusetts, and in other ecological settings. Wetlands representing these enduring features should support functional ecosystems with a diversity of species over time.

Using the same principles, Forest Cores, vernal pools, and Landscape Blocks were selected to ensure representation in each ecoregion. Ecoregions are geographic areas with similar topography, geology, and predominant vegetation, and therefore represent areas of relatively homogeneous ecological settings. By including intact ecosystems in each ecoregion, *BioMap2* again highlights the need to protect a diversity of functional ecosystems across the state in the context of a changing climate.

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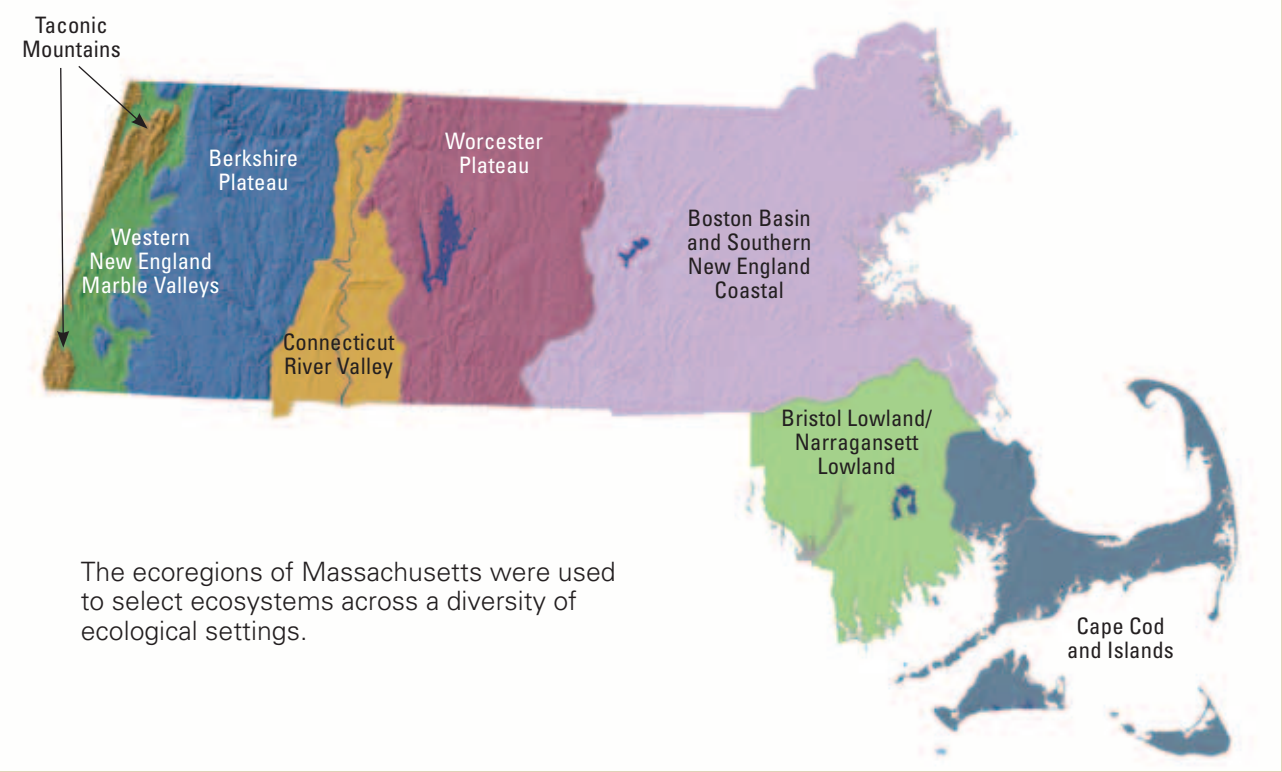


The ecoregions of Massachusetts were used to select ecosystems across a diversity of ecological settings.

COMPONENTS OF CORE HABITAT

Core Habitat identifies specific areas necessary to promote the long-term persistence of rare species, other Species of Conservation Concern, exemplary natural communities, and intact ecosystems. *BioMap2* uses specific data and sophisticated mapping and analysis tools to spatially define each of these components, calling on the latest research and understanding of species biology, conservation biology, and landscape ecology.

Species Habitat delineated for the Imperial Moth *(Eacles imperialis),* state-listed as Threatened, based on documented records of individuals.

This large silk moth feeds on Pitch Pine needles as a caterpillar, and is currently only known from Martha's Vineyard. The Pitch Pine forest in proximity to the records is delineated as prime habitat for this species.

Rare Species

A critical source of fine-filter information for *BioMap2* was the Natural Heritage & Endangered Species Program (NHESP) database for the 435 native plant and animal species listed under the Massachusetts Endangered Species Act (MESA). For inclusion on the MESA List, a species must meet strict criteria based on rarity, population trends, and threats to survival. Species on the MESA List are categorized as Endangered, Threatened, or Special Concern depending on their likelihood of extinction or extirpation. Information on these species is stored in a database containing nearly 10,000 rare species records that are geographically referenced. These records are based on field observations and undergo rigorous evaluation for inclusion into the system.

Using the observation records in the NHESP database, Natural Heritage biologists with expertise regarding these species delineated the extent of the critical habitat associated with each record, following species-specific mapping guidelines. Thus, a Species Habitat delineated for a plant whose seeds are dispersed only locally by ants will be significantly smaller and much more limited by human infrastructure (e.g., roads and buildings) than a Species Habitat delineated for a rare dragonfly that can quickly traverse large distances regardless of fragmentation by roads.

Because *BioMap2* is a statewide conservation prioritization tool, not every location where a MESA-listed species occurs is included as Core Habitat. While every part of the natural landscape contributes to the biodiversity of the state in some way, *BioMap2* is intended to identify the highest quality sites within the Commonwealth to help guide land protection and stewardship over the next decade. Therefore, it was necessary to evaluate every rare species habitat to determine which are most likely to persist over time. To do so, NHESP staff employed standard Natural Heritage methodology to rank each site based on size, condition, and landscape context. No records that were more than 25 years old were included in *BioMap2*.

Other Species of Conservation Concern

Another suite of fine-filter conservation targets in *BioMap2* was derived from the State Wildlife Action Plan (SWAP). This plan was developed by the Division of Fisheries and Wildlife (DFW) in 2005 to help guide wildlife conservation in Massachusetts in the coming decades. This document identifies 257 wildlife species and 22 natural habitats most in need of conservation within the Commonwealth. In addition to species on the MESA List described previously, SWAP identifies other wildlife species that are of significant regional conservation concern but do not meet the requirements for inclusion in the regulatory framework of the Massachusetts Endangered Species Act.

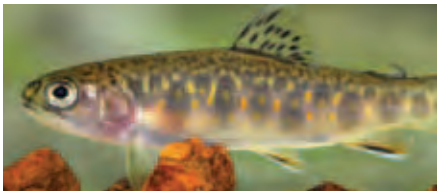
Of the nonlisted Species of Conservation Concern highlighted in SWAP, 45 species are directly mapped for inclusion in *BioMap2*. A variety of techniques were used to delineate species-specific habitat footprints. For 14 mammal, bird, amphibian, reptile, and invertebrate species, an approach similar to the creation of rare Species Habitats was used in which individual observations were compiled and a species-specific habitat footprint was added to Core Habitat.

Taxonomic Group	MESA-listed Species	Nonlisted Species of Conservation Concern
Mammals	4	5
Birds	27	23
Reptiles	10	5
Amphibians	4	3
Fish	10	17
Invertebrates	102	9
Plants	256	0
TOTAL	**413**	**62**

Species of Conservation Concern described in the State Wildlife Action Plan and/or included on the MESA List and for which habitat was mapped *directly* in *BioMap2*.

Note that plants are not included in SWAP, and that marine species such as whales and sea turtles are not included in *BioMap2*.

For the remaining 31 species, such as the Whip-poor-will, mapping of all individual occurrences was impractical. Instead, exemplary habitats, identified through expert knowledge of the distribution and biology of each species, were added to Core Habitat. Of these 31 species, *BioMap2* includes as Core Habitat examples of high-quality habitats for 13 nonlisted freshwater fish Species of Conservation Concern that occur in Massachusetts inland waters. These habitats were derived from both a detailed spatial database developed by the Fisheries Section of the Division of Fisheries and Wildlife and expert knowledge. The database is based on field sampling of over 3,000 locations, some sampled for multiple years. The portions of stream or river surrounding each of these sample points were delineated as Core Habitat, as well as adjacent wetlands falling within 30 meters of the edge of the stream or river. Since mapping fish habitat for *BioMap2* was driven by specific species in the fisheries spatial database, some exemplary habitats remain to be identified using other targets and techniques.



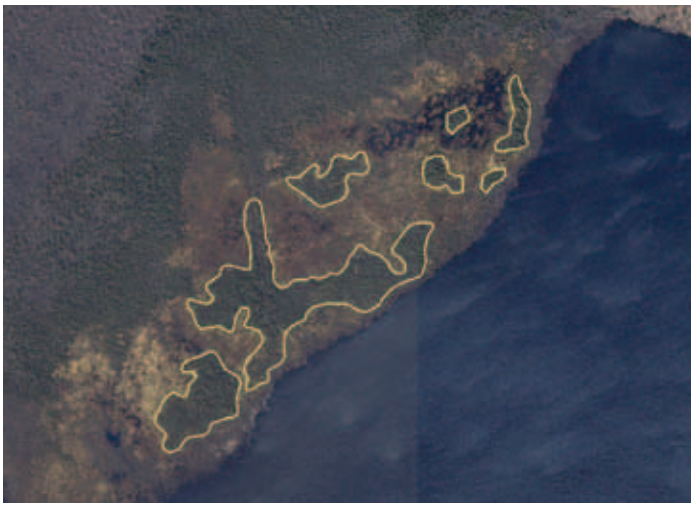
Eastern Brook Trout *(Salvelinus fontinalis)*

In addition to the freshwater fish habitat described above, *BioMap2* identifies high-quality Core Habitat for four nonlisted anadromous fish species: Rainbow Smelt, American Shad, Alewife, and Blueback Herring. These fish migrate between salt and fresh water, and for *BioMap2* river and lake habitat were selected that had self-sustaining populations and suitable spawning and nursery habitat. Stream-specific data were derived from Massachusetts Division of Marine Fisheries technical reports, supplemented with expert input.

The selection of these sites is supported by assessments including river sampling and fish counts at fishways maintained at hydroelectric dams and other passage obstructions. The selected streams were also delineated to include 30 meters adjacent to each stream and intersecting wetlands, as was done for freshwater fish.

Mapping method for nonlisted Species of Conservation Concern	Number of species
Individual observations used to delineate species habitat (akin to listed Species Habitats)	14
Identification of exemplary habitat through expert input	31
Mapped indirectly by other coarse-filter or fine-filter analyses	17
Not mapped due to lack of information or generalist nature of habitat use	18
TOTAL	**80**

For an additional 17 Species of Conservation Concern, the creators of *BioMap2* did not explicitly map high-quality areas for each species based on specific documented records. Instead, other *BioMap2* fine-filter and coarse-filter analyses include important habitat for each of these 17 species. For instance, the Landscape Blocks and Forest Cores include extensive areas that will support Black Bears, Bobcats, and other wide-ranging species. The Wetland Cores identified across the state, especially those in the western and central portion of Massachusetts, will benefit Moose. The Forest Cores capture important habitat for several interior-forest-dwelling birds (Northern Goshawk, Wood Thrush, Broad-winged Hawk, and White-throated Sparrow). Other species of concern are captured by mapping exemplary wetlands, rivers, and coastal habitats.



An example of Atlantic White Cedar Bogs delineated using aerial photographs and on-the-ground data collection.

Priority Natural Communities

Natural communities are defined as interacting assemblages of plant and animal species that share a common environment and occur together repeatedly on the landscape. 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. Terrestrial communities include forests, rocky ridgetops, shrublands, and beaches; palustrine 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 the creation of *BioMap2*, conservation priority was 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. These uncommon and exemplary natural communities were inventoried in the field and mapped using aerial photograph interpretation. Based on assessment of their size, condition, and landscape context, 782 examples of 94 of these Priority and Exemplary Natural Community types are included as Core Habitat in *BioMap2*. Conservation of these areas will support the persistence of characteristic common as well as rare species within Massachusetts.

Vernal Pools

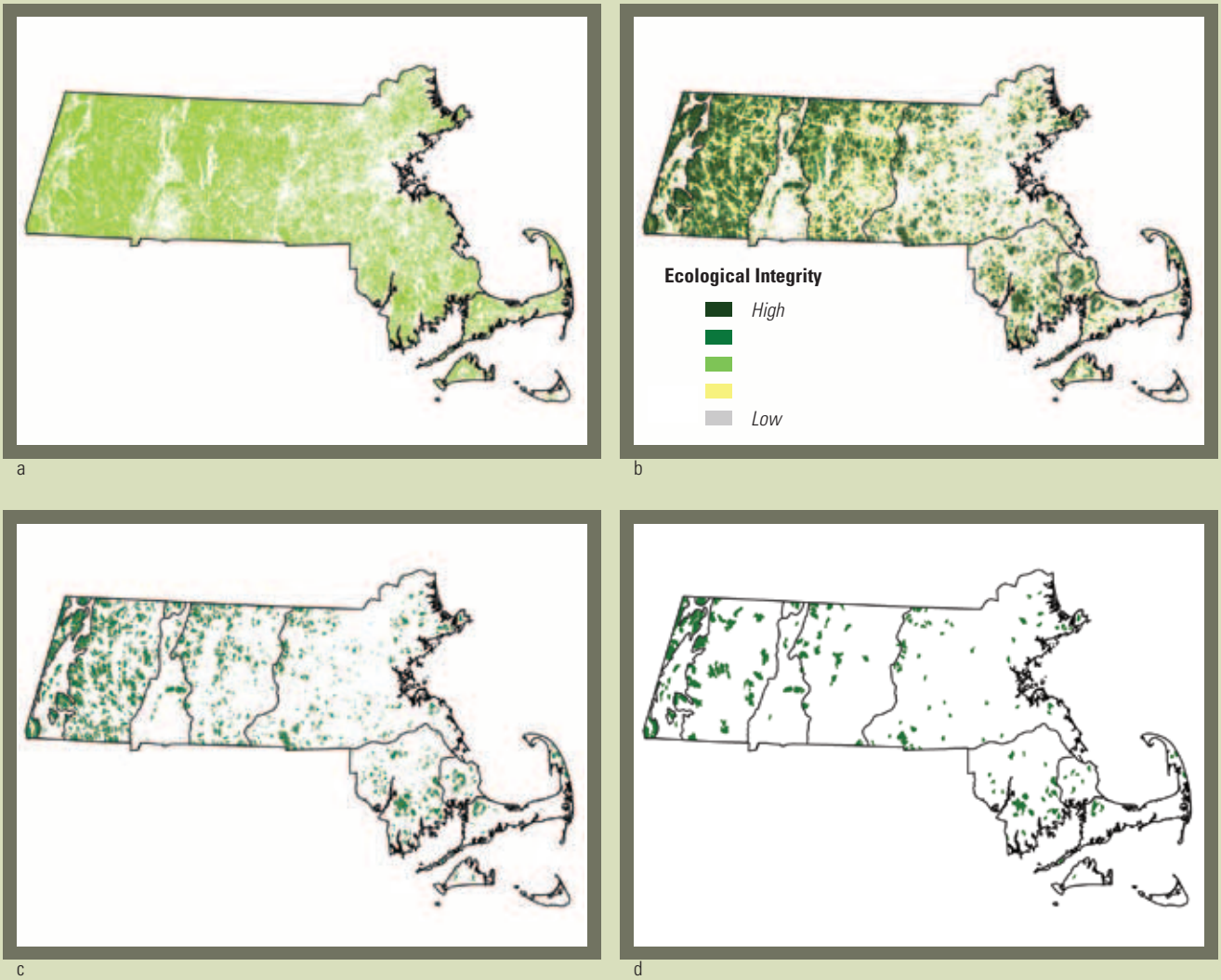
Two clusters of vernal pools identified in *BioMap2*.

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 database, systematically locating potential vernal pool habitat from aerial photographs. The creators of *BioMap2* used a GIS model developed by the University of Massachusetts Landscape Ecology Program to identify the top 5 percent most interconnected clusters of these Potential Vernal Pools. Each cluster of pools was then buffered to create vernal pool habitat areas to target for conservation that include the pools themselves and the surrounding habitat to allow for successful breeding, dispersal, overwintering, foraging, and migration. 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.

Calcareous fen, a rare wetland type in western Massachusetts

Forest Cores

In *BioMap2*, Core Habitat includes the best examples of large, intact forests that are least impacted by roads and development, providing critical habitat for numerous woodland species. For example, the interior forest habitat defined by Forest Cores supports many bird species sensitive to the impacts of roads and development, such as the Black-throated Green Warbler, and helps maintain ecological processes found only in unfragmented forest patches. Of the approximately 3 million acres of forest and forested wetlands in Massachusetts, the largest and least fragmented forests in each ecoregion were selected based on the Ecological Integrity assessment. Minimum forest patch sizes range from about 500 acres in eastern Massachusetts and the Connecticut and Housatonic Valleys, to 1,500 to 2,000 acres on the Worcester and Berkshire Plateaus, to over 3,000 acres in the Taconic Mountains.

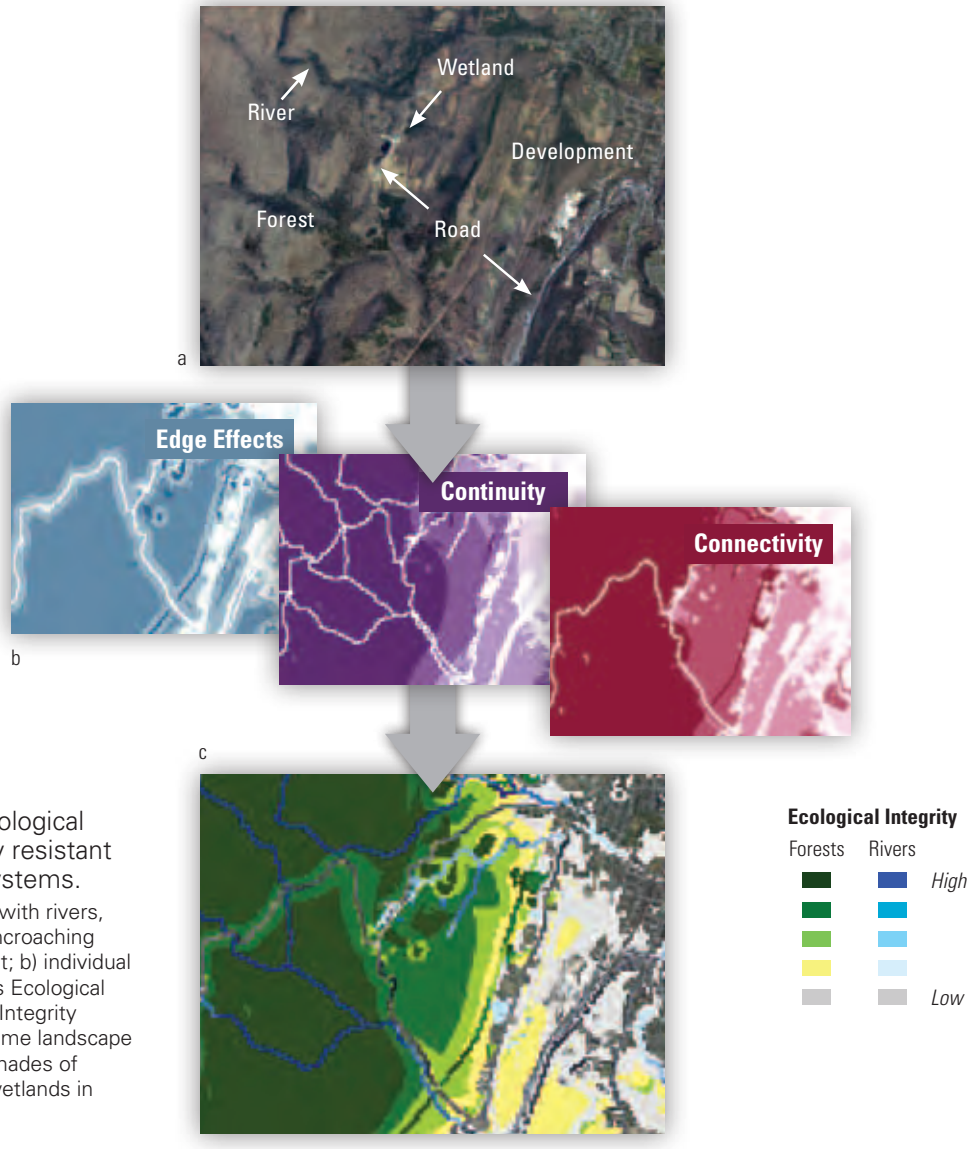


Selection of Forest Core for *BioMap2*, identifying forest interior habitat: a) map of forest cover in Massachusetts, b) the same forests categorized by Ecological Integrity, c) selection of highest integrity forests across the state, d) final selection based on size thresholds in each ecoregion.

ECOLOGICAL INTEGRITY: MAPPING ECOLOGICAL RESILIENCE

A primary goal of *BioMap2* is to identify the most resistant and resilient ecosystems in Massachusetts. To accomplish this, *BioMap2* objectively assessed all of the forests, wetlands, and large landscapes across Massachusetts using the Conservation Assessment and Prioritization System (CAPS), a sophisticated spatial model of Ecological Integrity developed over the past decade by researchers in the Landscape Ecology Program at the University of Massachusetts, Amherst.

The GIS model located the most intact and least fragmented forests, wetlands, and landscapes—those with few edge effects, high local habitat connectivity, and low road density and traffic volumes. The analysis started with maps of ecosystems (forests, rivers, wetlands) across the state. These data were used in combination with the best available data on ecological threats such as roads, traffic volume, development, dams, pollution sources, and intensive agriculture, to quantify fragmentation, edge effects, pollution, hydrological and biological alteration, and connectivity. Using these metrics, each point on the ground—hundreds of thousands of 30 meter by 30 meter grid cells across Massachusetts—was assessed and an Ecological Integrity score was calculated for every grid cell.



Assessment of Ecological Integrity to identify resistant and resilient ecosystems.

a) Forested landscape with rivers, small wetlands, and encroaching roads and development; b) individual metrics used to assess Ecological Integrity; c) Ecological Integrity interpretation of the same landscape with upland forest in shades of green and rivers and wetlands in shades of blue.

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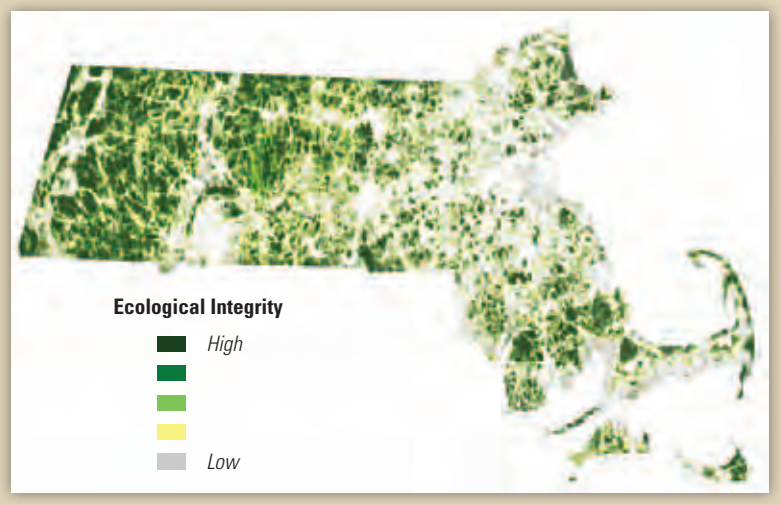


Ecological Integrity map of Massachusetts

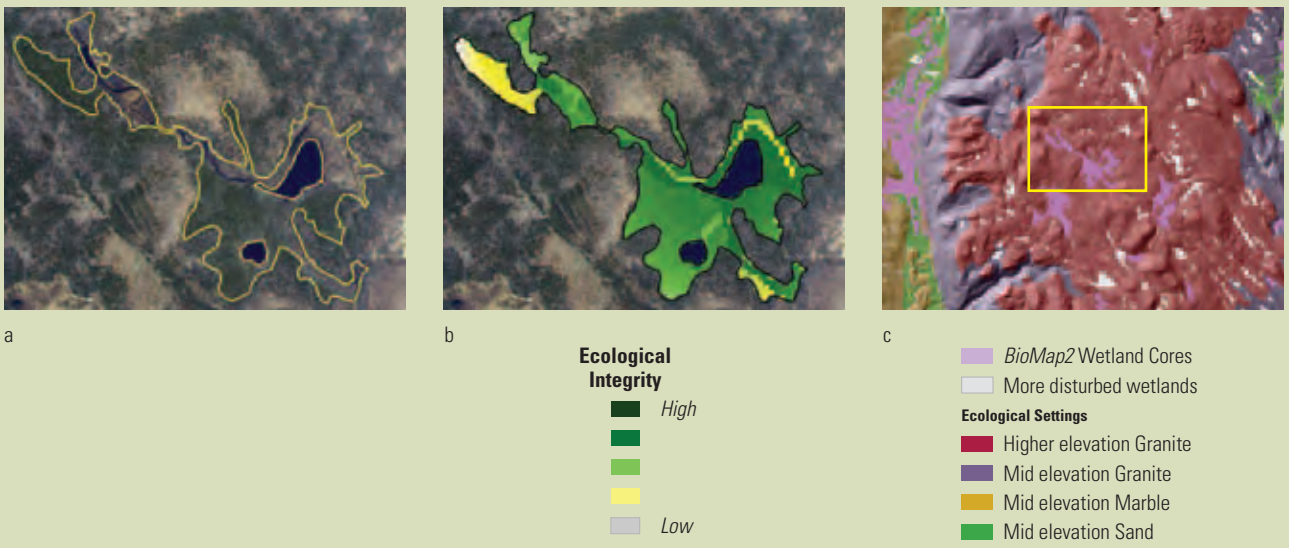
By looking at all the points across Massachusetts, the CAPS analysis identified clusters of high Ecological Integrity that represent the most intact ecosystems. Because these areas are not heavily impacted by development, they are likely to have high ecological resistance and resilience, and to support the natural processes necessary to sustain biodiversity over the long-term. The areas identified through this coarse-filter approach support a broad range of species and ecological processes, and complement other approaches used in *BioMap2* to prioritize areas for land protection and stewardship.

Wetland Cores

BioMap2 Core Habitat also includes a statewide assessment of the most intact wetlands in Massachusetts. This analysis identified the least disturbed wetlands within undeveloped landscapes—those with 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.

High-quality wetlands were identified using an assessment of Ecological Integrity. This analysis combined individual wetland types (e.g., shrub swamps, forested wetlands, marshes, bogs) into contiguous wetland complexes, selecting only those greater than 10 acres in order to prioritize long-term ecological function. Wetlands larger than 10 acres account for about 303,000 acres in Massachusetts.

BioMap2 identifies wetlands a) in intact settings, b) by calculating Ecological Integrity within each wetland and c) by selecting wetlands with the highest average integrity scores in each ecological setting across the state.



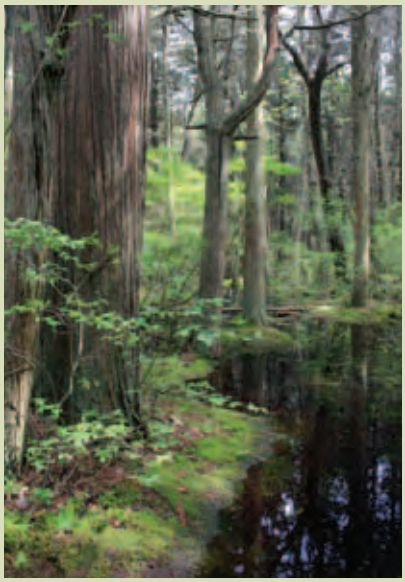
To enhance the biodiversity value of wetlands selected as Core Habitat, it is important to represent the varied ecological settings found in Massachusetts. In particular, different plant and animal assemblages occur in unique physical settings determined by geology and elevation. For instance, 108,000 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 in each ecological setting, *BioMap2* will help prioritize conservation of wetland diversity in the context of climate change. 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.

Aquatic Cores

To delineate integrated and functional ecosystems for fish species and other aquatic Species of Conservation Concern, beyond the species and exemplary habitats described above, *BioMap2* identified intact river corridors within which important physical and ecological processes of the river or stream occur. To identify those areas integrally connected to each river and stream, each river segment was buffered 30 meters. All wetlands wholly or partially contained within this buffer were then included, and the combination of the river channel, the adjacent buffer, and the connected wetlands make up the riverine Core Habitat.

Lateral expansion of river channel to define Core Habitat, creating a functional riparian corridor

Among several factors, elevation and underlying geology strongly influence wetland species distribution. Wetlands dominated by Atlantic White Cedar are found almost exclusively at low elevations along the coast, while wetlands dominated by Red Spruce and Tamarack are found at higher elevations and acidic bedrock in inland Massachusetts.



Atlantic White Cedar swamp

Spruce-tamarack bog

COMPONENTS OF CRITICAL NATURAL LANDSCAPE

Critical Natural Landscape was created to identify and prioritize intact landscapes in Massachusetts that are better able to support ecological processes and disturbance regimes, and a wide array of species and habitats over long time frames. Critical Natural Landscapes include: natural Landscape Blocks that are minimally altered by development; buffers for wetlands, rivers, and some aquatic species habitats delineated to help enhance their long-term integrity; and large intact areas important for the conservation of a wide-ranging habitat-generalist Special Concern species. *BioMap2* uses the latest understanding of conservation biology and landscape ecology to define Critical Natural Landscape.

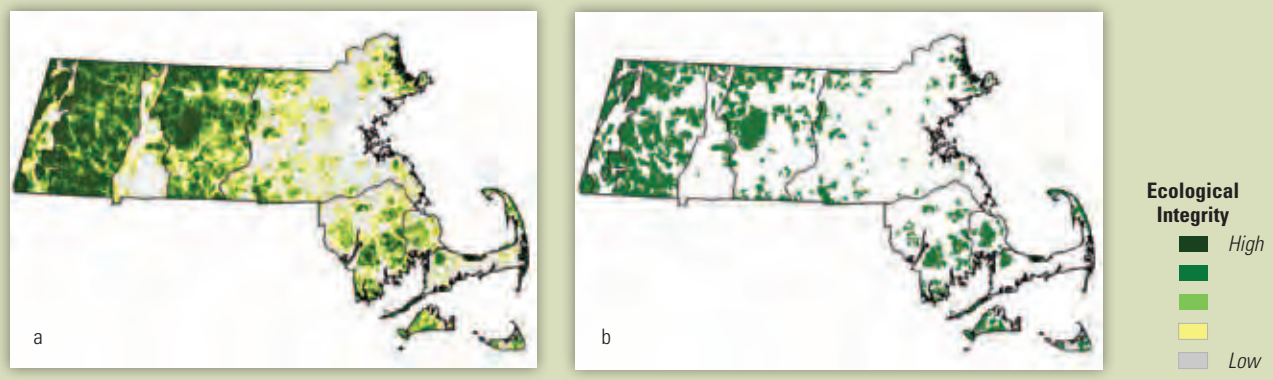
Aerial photo of a large Landscape Block dominated by forests; punctuated with wetlands, ponds, and rivers; and delineated to minimize harmful impacts from roads and development.

Landscape Blocks

Landscape Blocks, the primary component of Critical Natural Landscapes, are large areas of intact predominately natural vegetation, consisting of contiguous forests, wetlands, rivers, lakes, and ponds, as well as coastal habitats such as barrier beaches and salt marshes. Pastures and power-line rights-of-way, which are less intensively altered than most developed areas, were also included since they provide habitat and connectivity for many species.

Collectively, these natural cover types total 3.6 million acres across the state. The Ecological Integrity assessment was used to identify the most intact and least fragmented areas. These large Landscape Blocks are most likely to maintain dynamic ecological processes such as buffering, connectivity, natural disturbance, and hydrological regimes, all of which help to support wide-ranging wildlife species and many other elements of biodiversity. This analysis directly applied climate change adaptation strategies of selecting large, well-connected landscape patches with intact ecological processes, which are minimally impacted by other stressors. Additional habitat blocks were included in the Landscape Block delineations to support viable populations of the Special Concern Eastern Box Turtle to protect this wide-ranging, but vulnerable, habitat generalist.

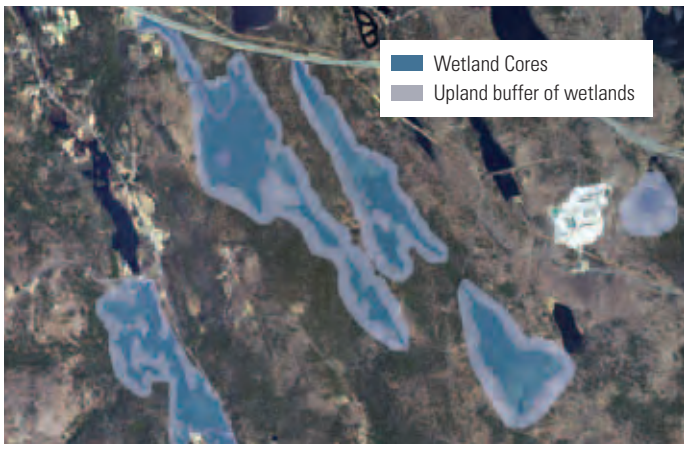
In order to identify critical Landscape Blocks in each ecoregion, different Ecological Integrity thresholds were used to select the largest intact landscape patches in each ecoregion while avoiding altered habitat as much as possible. This ecoregional representation accomplishes a key goal of *BioMap2* to protect the ecological stages that support a broad suite of biodiversity in the context of climate change. Blocks were defined by major roads, and minimum size thresholds differed among ecoregions to ensure that *BioMap2* includes the best of the best in each ecoregion.



Delineation of Landscape Blocks across the state: a) Natural vegetation cover categorized by Ecological Integrity, b) High Integrity Landscape Blocks defined by major roads, and selected using size thresholds specific to each ecoregion.

Core Habitat Buffers

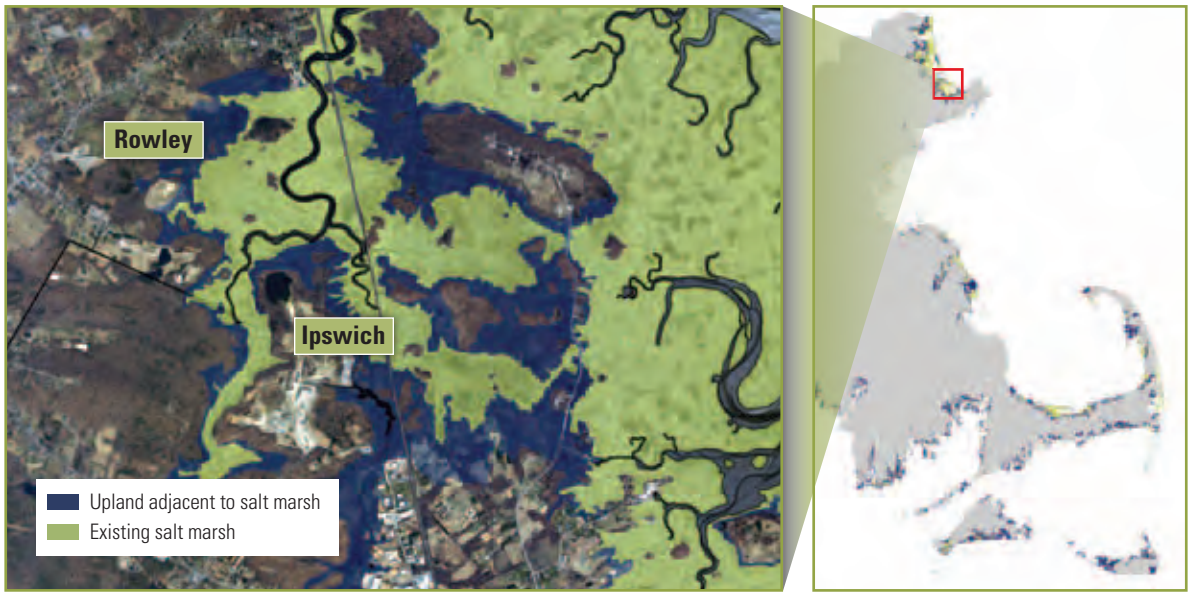
A variety of analyses were used to identify protective upland buffers around wetlands and rivers. One, the variable width buffers methodology, included the most intact areas around each wetland and river, by extending deeper into surrounding unfragmented habitats than into developed areas adjacent to each wetland. In this way, the conservation of wetland buffers will support the habitats and functionality of each wetland, and also include adjacent uplands that are important for many species that move between habitat types.



Wetlands in dark blue showing variable-width buffers in light blue extending into intact uplands

Coastal Adaptation to Sea-Level Rise

The coastal habitats of Massachusetts are particularly vulnerable to potential sea-level rise in the next century, which many estimates suggest is likely to exceed one meter. Therefore, in addition to prioritizing current coastal habitats, the creators of *BioMap2* examined the landward side of salt marshes to determine where these habitats might move to as sea levels rise. Undeveloped lands adjacent to and up to one and a half meters above existing salt marshes were identified, and included as Critical Natural Landscapes with high potential to support inland migration of salt marsh and other coastal habitats over the coming century.

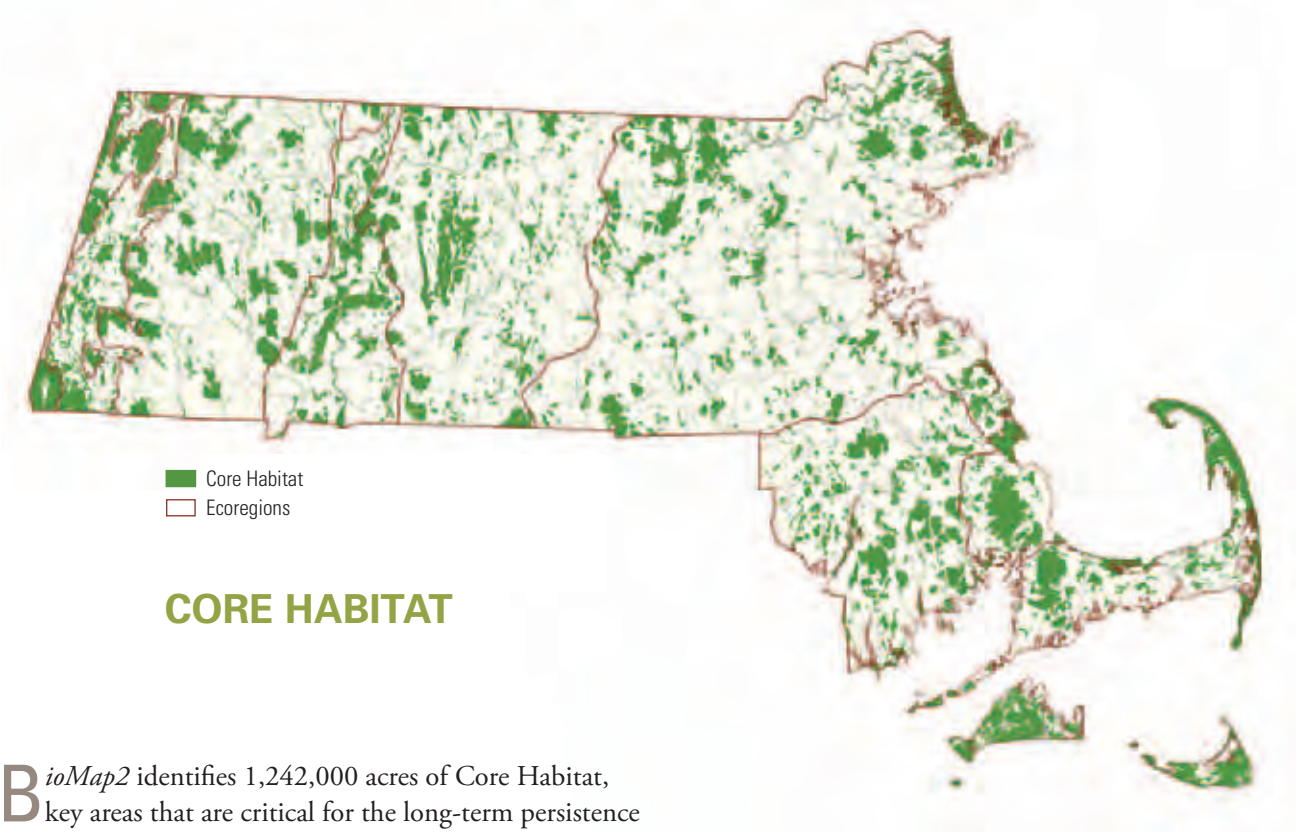


BioMap2 coastal adaptation analysis, conducted for the entire coast of Massachusetts

The conservation areas identified by *BioMap2* are based on breadth and depth of data, scientific expertise, and understanding of Massachusetts' biodiversity. The numerous sources of information and analyses used to create Core Habitat and Critical Natural Landscape are complementary, and outline a comprehensive conservation vision for Massachusetts, from rare species to intact landscapes. In total, these robust analyses define a suite of priority lands and waters that, if permanently protected, will support Massachusetts' natural systems for generations to come.

CHAPTER 4

BioMap2: Core Habitat and Critical Natural Landscape



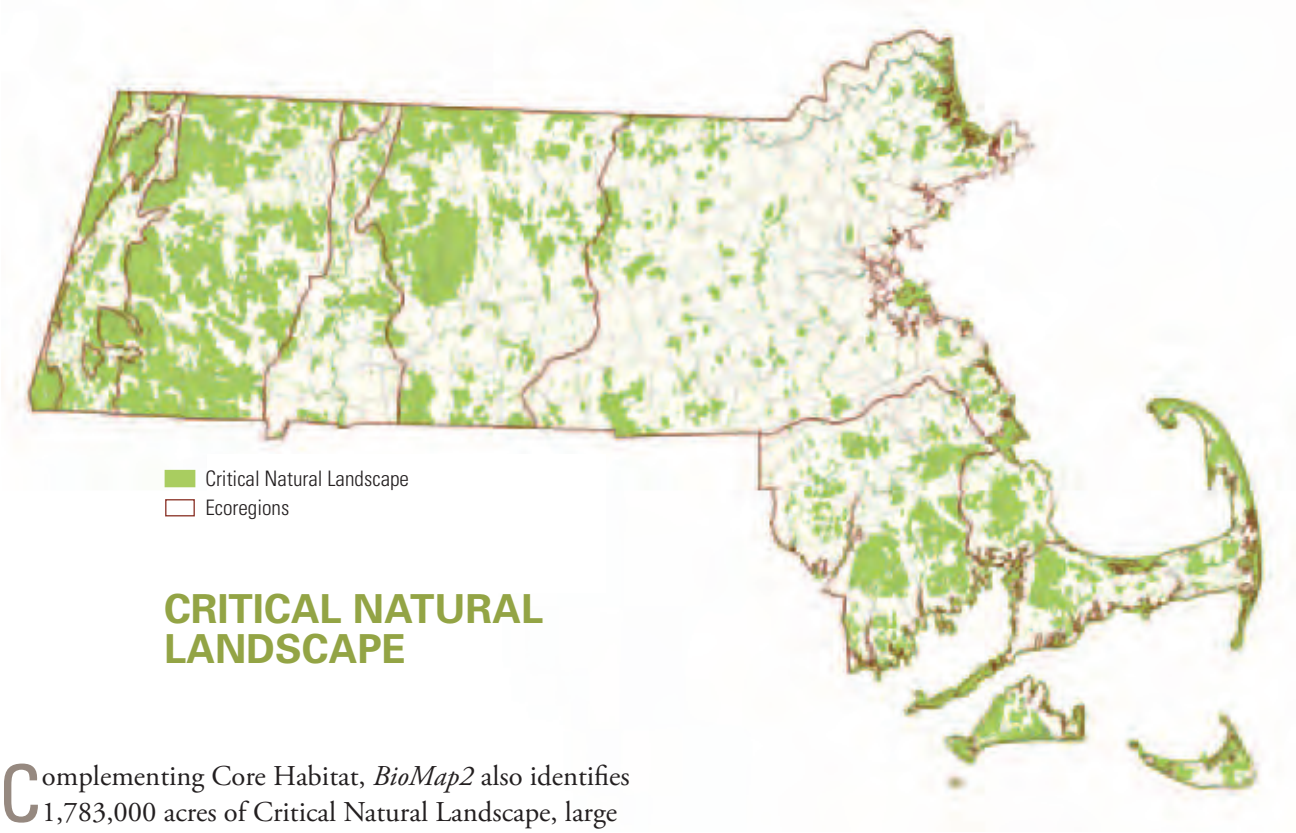
CORE HABITAT

BioMap2 identifies 1,242,000 acres of Core Habitat, key areas that are critical for the long-term persistence of rare species and other Species of Conservation Concern, as well as a wide diversity of natural communities and intact ecosystems across the Commonwealth. In total, Core Habitat identifies 943,000 acres of upland habitat, 233,000 acres of wetland and aquatic habitat, and includes 2,700 miles of rivers and streams specifically selected to protect aquatic species and ecosystems.

Core Habitat specifically includes

- 256 Plant species
- 111 Invertebrates
- 50 Birds
- 15 Reptiles
- 7 Amphibians
- 9 Mammals
- 94 Priority Natural Communities
- 36,000 acres of High quality vernal pool habitat
- 325,000 acres of Forest Core
- 93,000 acres of Wetland Core
- 220,000 acres of Aquatic Core

Ecoregion	Core Habitat (Acres)	Percent of ecoregion
Berkshire Plateau	184,000	23%
Boston Basin and Southern New England Coastal	316,000	18%
Bristol and Narragansett Lowlands	139,000	23%
Cape Cod and Islands	211,000	44%
Connecticut River Valley	97,000	28%
Taconic Mountains	57,000	63%
Western New England Marble Valleys	60,000	27%
Worcester Plateau	178,000	20%



CRITICAL NATURAL LANDSCAPE

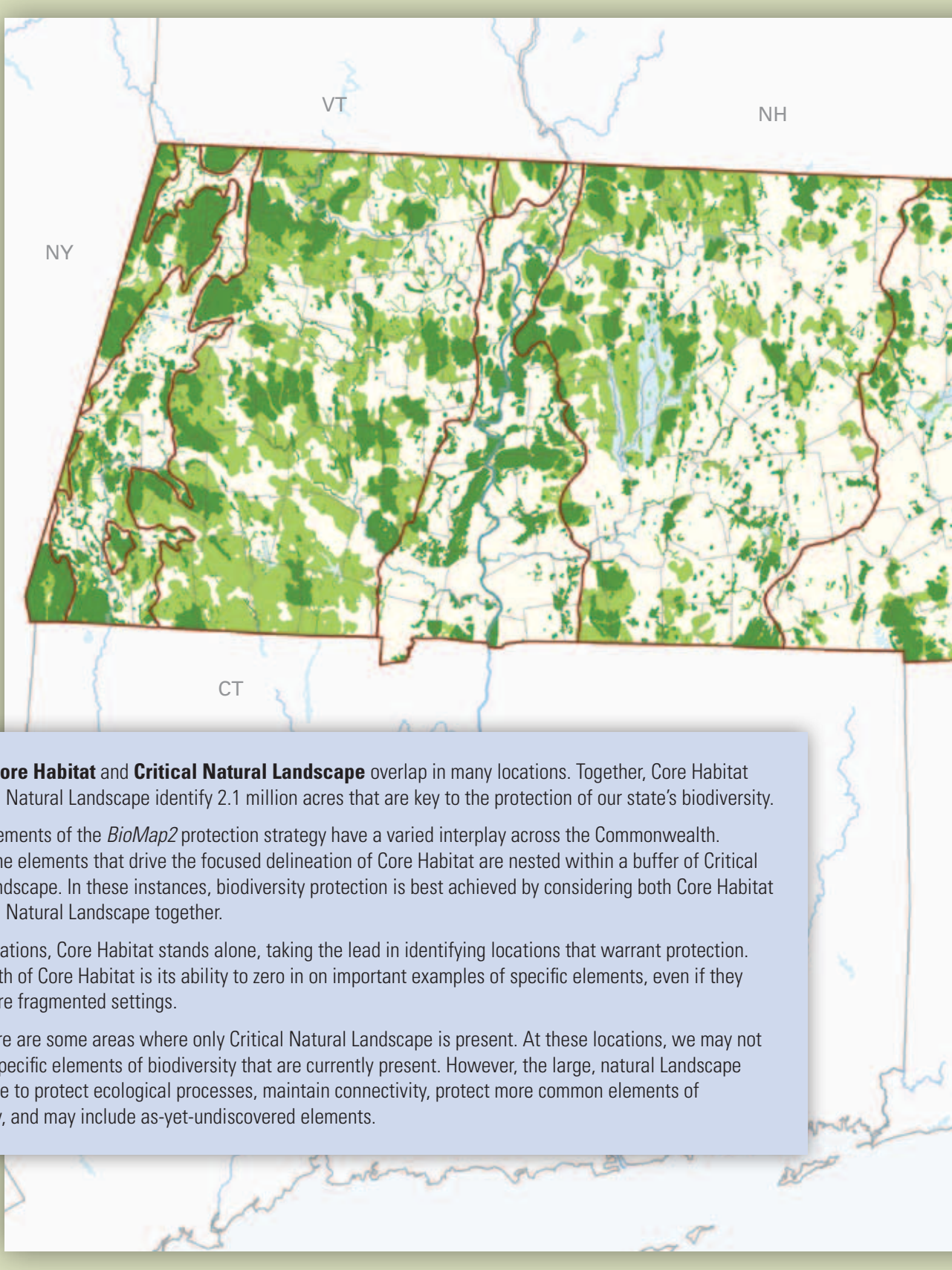
Complementing Core Habitat, *BioMap2* also identifies 1,783,000 acres of Critical Natural Landscape, large natural Landscape Blocks that provide habitat for wide-ranging native species, support intact ecological processes, maintain connectivity among habitats, and enhance ecological resilience, as well as buffering land around coastal, wetland, and aquatic Core Habitats to help ensure their long-term integrity.

Critical Natural Landscape includes

- The largest Landscape Blocks in every ecoregion
- Adjacent upland habitat supporting Wetland Cores
- Adjacent upland habitat supporting Aquatic Cores
- Areas supporting coastal adaptation, with high potential to support inland migration of salt marshes

Ecoregion	Critical Natural Landscape (Acres)	Percent of ecoregion
Berkshire Plateau	488,000	61%
Boston Basin and Southern New England Coastal	273,000	16%
Bristol and Narragansett Lowlands	206,000	35%
Cape Cod and Islands	219,000	46%
Connecticut River Valley	86,000	25%
Taconic Mountains	75,000	83%
Western New England Marble Valleys	87,000	40%
Worcester Plateau	349,000	38%

BIOMAP2: ONE PLAN, TWO COMPONENTS



BioMap2 **Core Habitat** and **Critical Natural Landscape** overlap in many locations. Together, Core Habitat and Critical Natural Landscape identify 2.1 million acres that are key to the protection of our state's biodiversity.

The two elements of the *BioMap2* protection strategy have a varied interplay across the Commonwealth. At times, the elements that drive the focused delineation of Core Habitat are nested within a buffer of Critical Natural Landscape. In these instances, biodiversity protection is best achieved by considering both Core Habitat and Critical Natural Landscape together.

In other locations, Core Habitat stands alone, taking the lead in identifying locations that warrant protection. One strength of Core Habitat is its ability to zero in on important examples of specific elements, even if they exist in more fragmented settings.

Finally, there are some areas where only Critical Natural Landscape is present. At these locations, we may not know the specific elements of biodiversity that are currently present. However, the large, natural Landscape Blocks serve to protect ecological processes, maintain connectivity, protect more common elements of biodiversity, and may include as-yet-undiscovered elements.


Core Habitat
Critical Natural Landscape
Ecoregions
RI

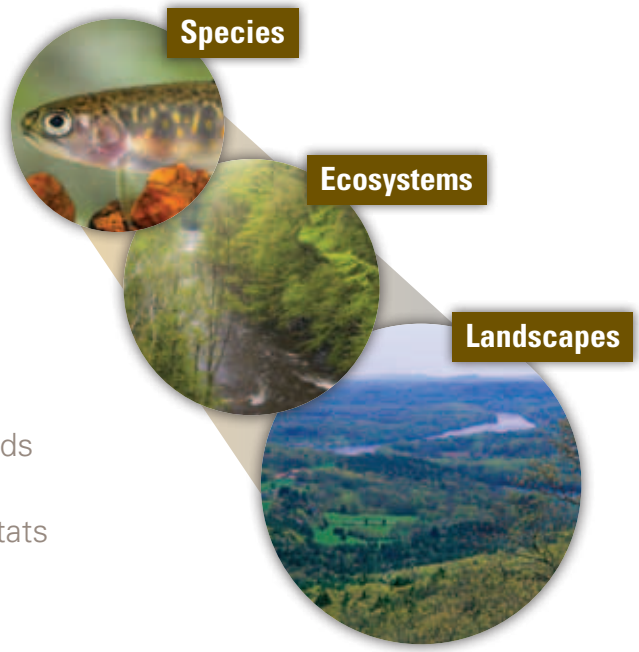
CHAPTER 5
The Elements of Biodiversity

The native biodiversity of Massachusetts is a rich and varied tapestry of different organisms that have complex interactions and specific requirements for survival. Invertebrates such as insects and mussels are as significant to biodiversity as plants, mammals, birds, fish, reptiles, and amphibians. Each thread is a necessary part of the tapestry. At broader scales, complex ecosystems support suites of plant and animal species that occur together in geologically and topographically similar settings. Ecosystem-scale conservation ensures that, across Massachusetts, multiple examples of each habitat type, and its associated ecosystem processes, are protected, providing habitat for the full range of native species as well as ecosystem resilience.

BioMap2 is a map of Massachusetts' critical areas for biodiversity conservation, encompassing multiple species and ecosystems. But what is the importance of each component of biodiversity to the richness of Massachusetts' ecology, how much habitat for each component is included in *BioMap2*, and how is it distributed across the state? What are the primary threats facing individual conservation targets, and how much Core Habitat and Critical Natural Landscape currently remain unprotected?

Although each and every element of biodiversity is significant, no individual component adequately addresses the biodiversity conservation needs of the Commonwealth. The various conservation targets are ecologically linked in numerous and complex ways and many occur in the same location. In *BioMap2*, species and natural communities are explicitly mapped, and extensive forests, wetlands, rivers, and landscapes provide important habitat for both rare and common species and the processes necessary to sustain them. Core Habitat and Critical Natural Landscape are complementary, and the long-term conservation of the biodiversity of Massachusetts requires protection and stewardship of the integrated network of species habitats, ecosystems, and natural landscapes presented in *BioMap2*.

CONTENTS OF CHAPTER 5



SPECIES OF CONSERVATION CONCERN

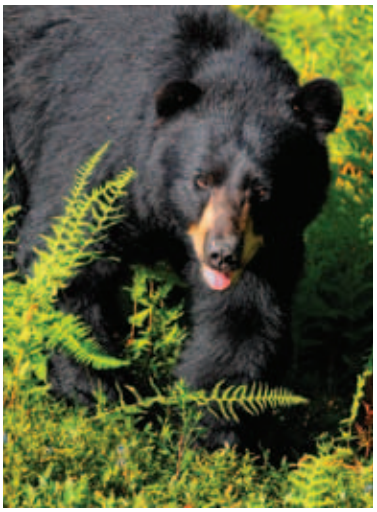
MAMMALS: FROM BATS TO BEARS

Mammals include the largest animals in Massachusetts, such as the wide-ranging Black Bear and Moose that are characteristic of the largest intact wildlife habitats in the Northeast. More than 80 species of mammals occur in Massachusetts. Five terrestrial mammals that are quite rare are protected under the Massachusetts Endangered Species Act, including two shrews (Water Shrew and Rock Shrew), two bats (Indiana Myotis and Small-footed Myotis), and a bog lemming (Southern Bog Lemming).

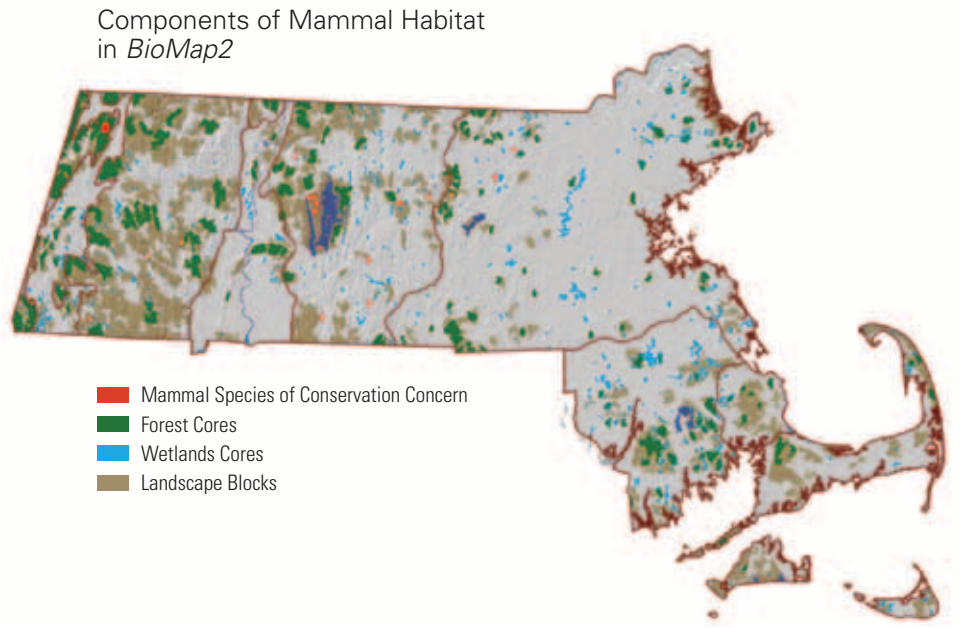
Indiana Myotis, which is also federally Endangered, has not been documented in the state since 1939, and all six bat species that hibernate in Massachusetts are now seriously threatened by white-nose syndrome, which has virtually wiped out the major hibernating colonies in Massachusetts and surrounding states.

Approximately 10,800 acres of habitat are included in *BioMap2* as Core Habitat for the five terrestrial MESA-listed mammal species plus the New England Cottontail (currently a candidate for federal listing status). *BioMap2* Forest Cores, Wetland Cores, and Landscape Blocks also include 1,511,000 acres likely to provide high-quality habitats in much of the state for terrestrial mammals of conservation concern including larger, wide-ranging mammals such as Moose, Black Bears, and Bobcat. Fifty-three percent of the total terrestrial mammal habitat mapped is currently unprotected.

Moose *(Alces alces)*



Black Bear *(Ursus americanus)*



BIRDS: A RICH AND COLORFUL ARRAY OF SPECIES

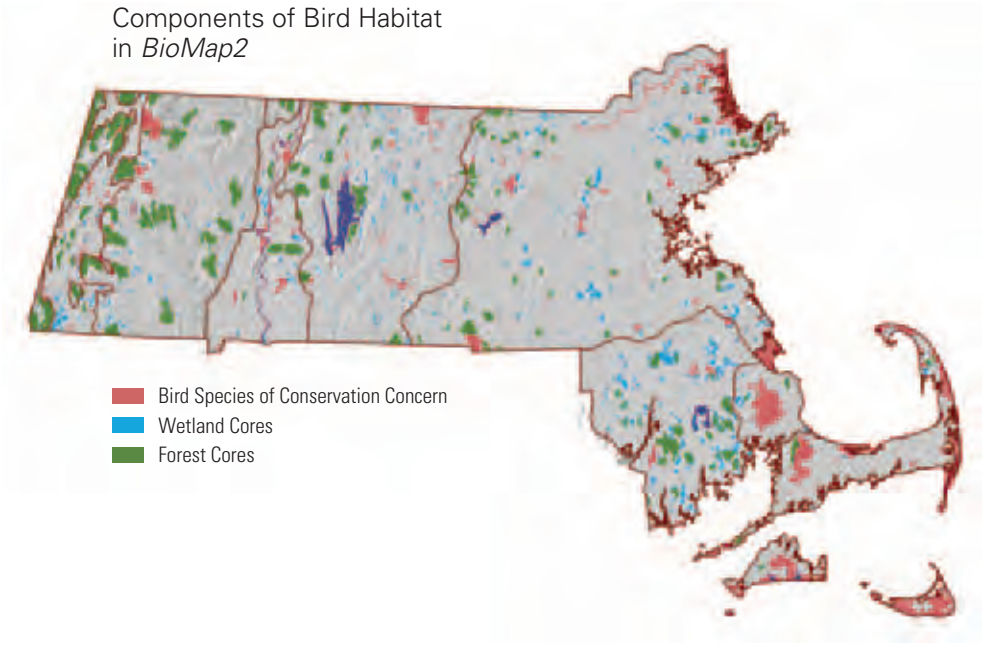
Canada Warbler *(Wilsonia canadensis)*

American Bittern *(Botaurus lentiginosus)*, Endangered

As a result of a high diversity of habitats and the state's location along the Atlantic Flyway, Massachusetts supports an extremely rich avifauna. From the Berkshire Plateau to the tidal flats of Monomoy Island, over 460 species of birds have been recorded in Massachusetts, of which over 200 species breed in the Commonwealth. Our coastal habitats are of international conservation significance, supporting one-third of the Atlantic coast population of the Piping Plover, a federally Threatened species, and half of North America's breeding population of the Roseate Tern, a federally Endangered species. The world's largest wintering congregation of Long-tailed Ducks occurs off Nantucket, and staggering numbers of shorebirds, ducks, raptors, and songbirds rely on Massachusetts habitats as critical resting and refueling stations during their migratory journeys.

Massachusetts supports both southern and northern habitat types; as a result, many species that are at the edges of their ranges occur in the state. For example, Mount Greylock supports the southernmost breeding population of the Blackpoll Warbler. Similarly, the world's southernmost breeding Leach's Storm-Petrels and Arctic Terns are found on islands in Massachusetts waters, while southern marsh birds such as the King Rail and Common Moorhen are at their northern range limits in Massachusetts.

Several bird species that are experiencing range-wide population declines occur in the Commonwealth. Protecting and properly managing the habitats of these declining species is critical to their survival, and also helps to ensure that other species associated with these habitats will continue to thrive. *BioMap2* includes 272,000 acres of Core Habitat directly mapped for various bird Species of Conservation Concern. Habitat for several additional Species of Conservation Concern, such as the Northern Goshawk, Canada Warbler, and Green Heron, was included through the Forest Core and Wetland Core mapping (401,000 acres). Forty-six percent of the total bird habitats mapped is currently unprotected.



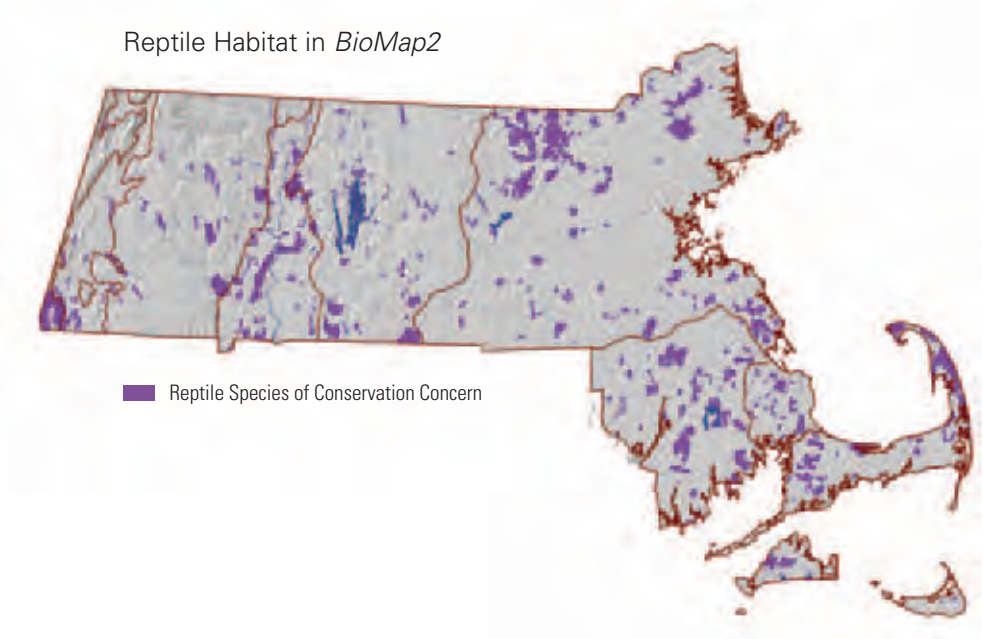
Common Tern *(Sterna hirundo)*, Special Concern, and Roseate Tern *(Sterna dougallii)*, Endangered

REPTILES: ANCIENT AND IMPERILED

Reptiles are one of the most vulnerable taxonomic groups in Massachusetts. Of 29 native reptile species, 19 (67%) are recognized as Species of Conservation Concern in the State Wildlife Action Plan. Eleven (73%) turtle species and 4 (29%) snake species are state listed and 7 (46%) of the turtle species are federally listed.

Preserving viable populations of both rare and common reptiles is a daunting challenge as a result of their population and life history characteristics and the degree of development pressure in much of Massachusetts. Many reptiles move annually among a variety of wetland and terrestrial habitats, often over distances of thousands of feet. For this reason, reptiles are highly susceptible to road mortality and other adverse effects of habitat fragmentation. Local populations of some species, such as the Eastern Box Turtle, occur at low densities. These species require relatively large areas of unfragmented wetland and terrestrial habitats in order to preserve viable populations.

BioMap2 includes 408,000 acres of Core Habitat for rare or uncommon reptiles, 57% of which remain unprotected.



Bog Turtle *(Glyptemys muhlenbergii)*, Endangered

Copperhead *(Agkistrodon contortrix)*, Endangered

Spotted Turtle *(Clemmys guttata)*

AMPHIBIANS: STRADDLING TWO REALMS

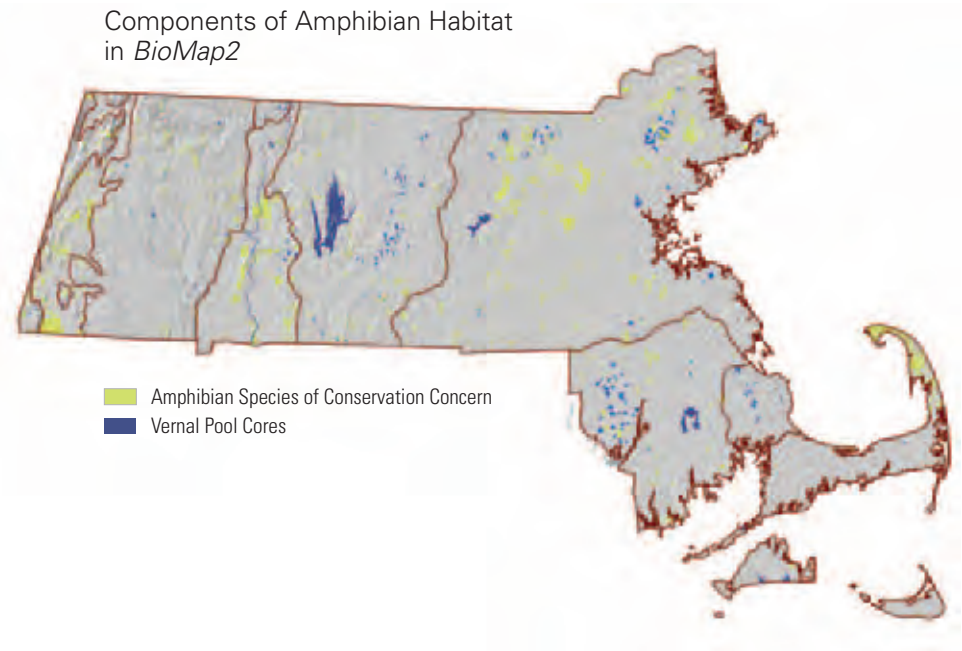
Blue-spotted Salamander
(Ambystoma laterale), Special Concern

Eastern Spadefoot Toad
(Scaphiopus holbrookii), Threatened

Most amphibians require freshwater habitat for breeding as well as terrestrial habitat for other parts of their life cycles. Because amphibians have three or four distinct life stages (e.g., egg, larva, juvenile, adult), they are crucial components of multiple levels of the food webs in a wide range of natural communities. Serving as both predators and prey, amphibians interact with a multitude of organisms ranging from tiny plankton and invertebrates to larger animals such as fish, snakes, raccoons, and herons. In Massachusetts, many amphibian species are associated with vernal pools—ephemeral, fish-free, freshwater wetlands. Because of their complex life histories and dependence on temporary wetlands for breeding, amphibians are highly sensitive to the impacts of climate change.

A total of 21 amphibian species are known to occur in Massachusetts. Of these, seven (33%) are identified as Species of Conservation Concern in the State Wildlife Action Plan, four of which (19%) are listed as Threatened or of Special Concern under the Massachusetts Endangered Species Act. Long-term protection of the habitats of these species is a critical priority. Approximately 152,000 acres of wetlands and upland forest are included in *BioMap2* as Core Habitat for the seven amphibian Species of Conservation Concern (e.g., Marbled Salamander, Eastern Spadefoot Toad, Northern Leopard Frog), of which approximately 58% are currently unprotected. An analysis of clusters of vernal pools and their associated upland habitat also identified 36,000 acres of likely amphibian habitat across the state.

Components of Amphibian Habitat in *BioMap2*



Spring Salamander
(Gyrinophilus porphyriticus)

FISH: INDICATORS OF HEALTHY RIVERS, STREAMS, AND PONDS

Massachusetts freshwater habitats currently support 57 species of fish. Many of our native fish species are restricted to the Atlantic Coastal Plain, and others are found nowhere else in the world. While most species are resident species, living out their life cycle entirely within Massachusetts' freshwater rivers, lakes, and ponds, others are diadromous, migrating between freshwater and the open ocean.

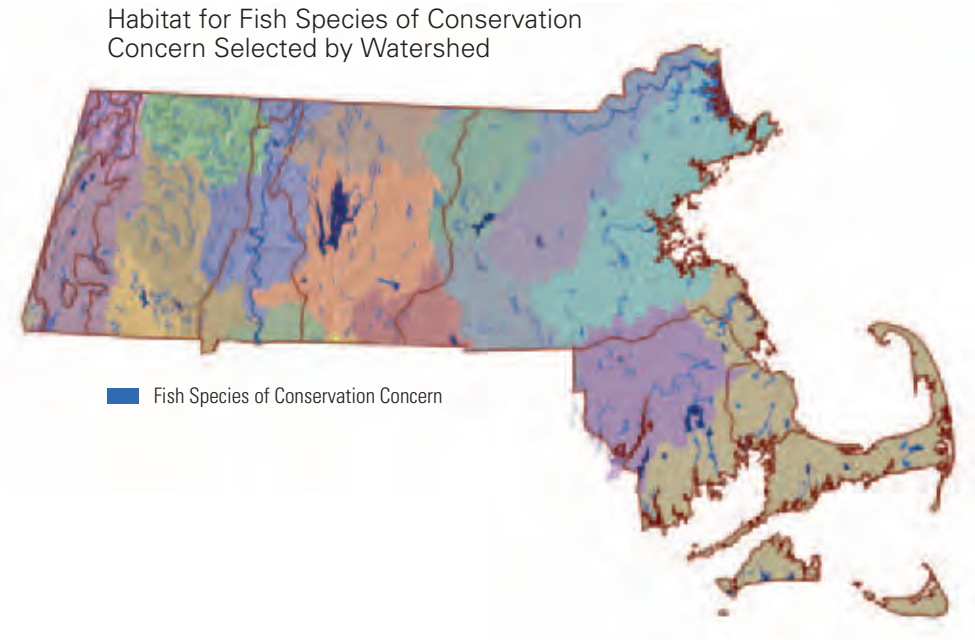
Alewife *(Alosa pseudoharengus)*

Lake Chub *(Couesius plumbeus)*, Endangered

Important cold-water, cool-water, and warm-water habitats occur across the Commonwealth, supporting 10 rare freshwater fish species, such as the Atlantic Sturgeon and Bridle Shiner, 18 additional Species of Conservation Concern, including the Eastern Brook Trout and the Banded Sunfish, and many common species. Massachusetts' extensive network of coastal rivers supports anadromous fish including historically important New England fisheries such as Blueback Herring and American Shad.

Threats to native fish include dams, pollution, urbanization, and water withdrawal. These factors have had significant negative impacts on river and lake habitats and have altered native fish distribution and abundance. Two native fish species—Trout-perch and Atlantic Salmon—were extirpated from Massachusetts, although a program to restore Atlantic Salmon to the Connecticut and Merrimack Rivers is ongoing. Long-term conservation of native fish species will require both protection of waterways and the lands that help to ensure healthy hydrological functioning, as well as a range of stewardship and restoration efforts to mitigate damage to important aquatic habitats.

Including connected wetlands, *BioMap2* Core Habitat contains 126,000 acres of freshwater and brackish habitat, and approximately 2,000 miles of streams and rivers. In addition, a wide range of important habitats for common fish species is included in Core Habitats as well as Critical Natural Landscapes.



INVERTEBRATES: DIVERSE AND IMPORTANT

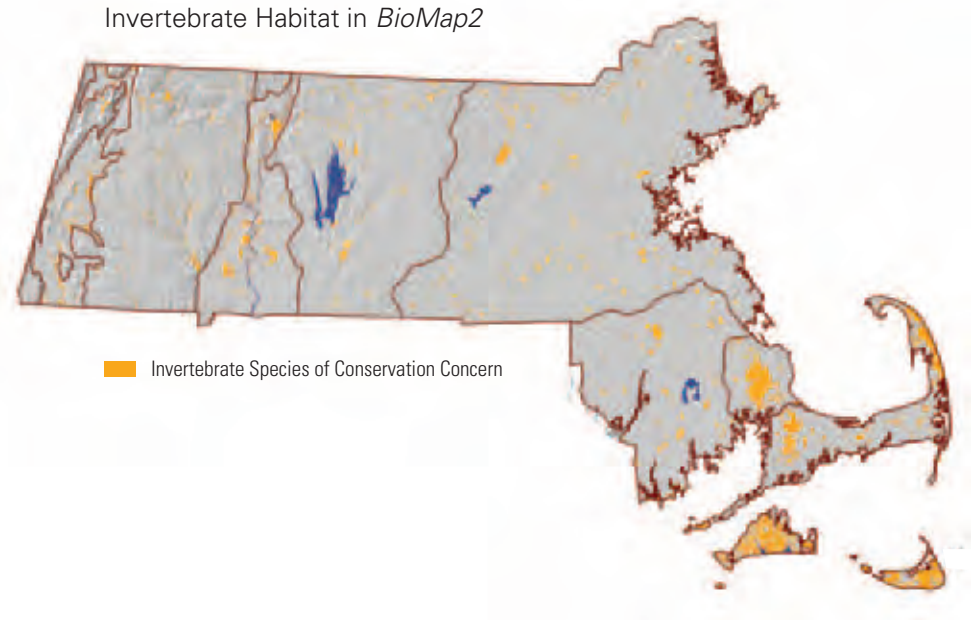
Spatterdock Darner *(Rhionaeschna mutata)*, Special Concern

Yellow Lampmussel *(Lampsilis cariosa)*, Endangered

Although often overlooked, invertebrates are an incredibly diverse and indispensable part of the natural world, providing food for other animals, pollinating both cultivated crops and wild plants, and recycling nutrients by consuming and decomposing organic materials. In Massachusetts, one can find over 100 species of butterflies, 167 species of dragonflies and damselflies, and more than 2,500 species of moths—each with its own fascinating life history and many that are strikingly beautiful.

Rare or uncommon invertebrates frequently have specialized habitat requirements. For example, pitch pine-scrub oak barrens, heathlands, and grasslands provide habitat for an unusually high concentration of rare moths, butterflies, and tiger beetles. Wetlands, particularly those with unpolluted, well-oxygenated waters, are home to many uncommon freshwater mussels, dragonflies, and damselflies. Because of their specialized habitat requirements and sensitivity to ecological alteration, these invertebrates tend to occur in pristine natural communities that also support a host of other rare plants and animals.

The major threats to rare invertebrates are habitat destruction and degradation. For aquatic species such as mussels, snails, and dragonflies, nutrient loading, water withdrawal, and chemical runoff from residential landscaping practices can have detrimental effects. Pine barrens have been dramatically reduced by development, and the habitat quality of most remaining barrens is compromised by fire exclusion. Many uncommon invertebrates are also threatened by invasive species that prey on, parasitize, or compete with native species. In addition to protecting critical habitat from development, proper management is also needed so that habitats remain suitable for threatened species. *BioMap2* includes 249,000 acres of Core Habitat for invertebrate Species of Conservation Concern, 54% of which is currently unprotected.



Phyllira Tiger Moth *(Grammia phyllira)*, Endangered

PLANTS: FROM ORCHIDS TO OAKS

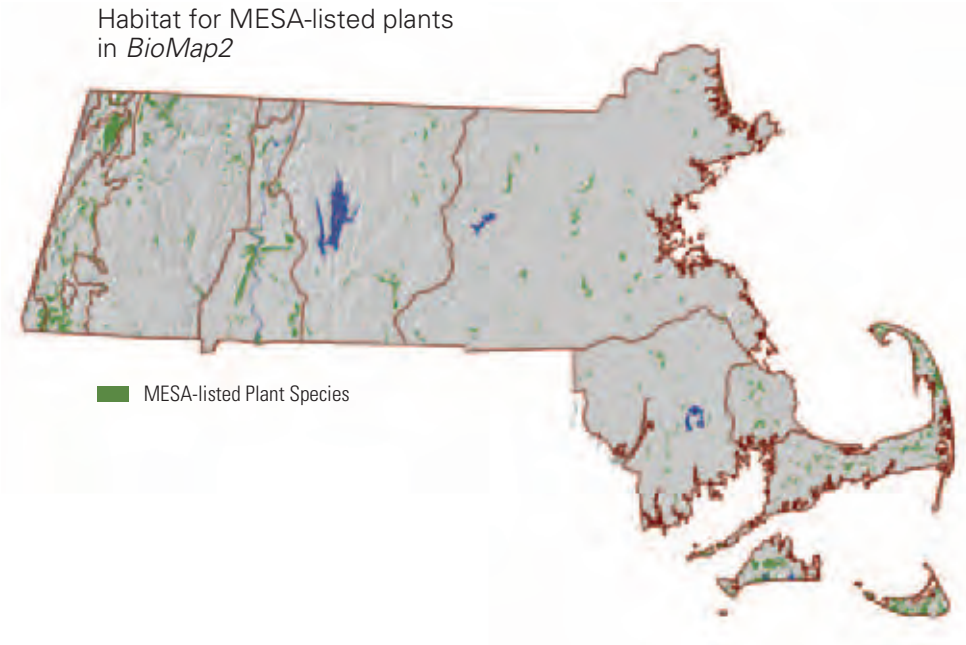
Massachusetts is home to a high diversity of vascular plant species, including approximately 1,770 native species, of which 14% are considered vulnerable to extirpation or local extinction and are protected by the Massachusetts Endangered Species Act. These species are quite varied, from the minuscule Weft Bristle-fern to the magnificent Showy Lady's-slipper orchid. Three federally listed plant species occur in the Commonwealth, with an additional 29 species that are globally rare or imperiled throughout their range. For species such as the Plymouth Gentian that have their worldwide stronghold in Massachusetts, the Commonwealth has particular responsibility for their careful stewardship and long-term survival.

Plant species are tightly interwoven into the ecological landscape, and many are indicators of unique places or processes that also provide habitat for rare or unusual animal species. Major threats to native plants vary by species, and include habitat destruction, fire suppression, off-road vehicle use, invasive plants, and intensive deer browsing. Effective conservation of uncommon plants in the Commonwealth requires both protection of habitat and long-term stewardship of habitat quality. *BioMap2* includes 107,000 acres of Core Habitat specifically mapped for rare plant species (45% of which is unprotected), as well as extensive wetland and upland habitats for a high diversity of more common species.

Plymouth Gentian *(Sabatia kennedyana)*, Special Concern

Tuckerman's Sedge *(Carex tuckermanii)*, Endangered

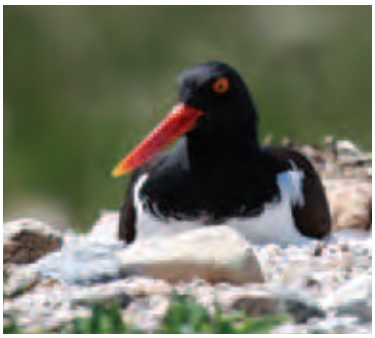
Showy Lady's-slipper *(Cypripedium reginae)*, Special Concern



New England Blazing Star *(Liatris scariosa var. novae-angliae)*

Northeastern Beach Tiger Beetle *(Cicindela dorsalis dorsalis),* Endangered

Diamondback Terrapin *(Malaclemys terrapin),* Threatened



American Oystercatcher *(Haematopus palliatus)*

ECOSYSTEMS: PROVIDING HABITAT FOR BIODIVERSITY

In addition to habitat for individual species, *BioMap2* identifies coastal, freshwater wetland, aquatic, open canopy (e.g. grasslands and barrens), and forest habitats for a broad suite of rare and more common species. The best examples of these coarse filter ecosystems will support diverse and dynamic populations over time.

COASTAL HABITATS: BEACHES, DUNES, AND ESTUARIES

Massachusetts has approximately 1,500 miles of coastline, more than any other New England state except Maine. The coast supports a tremendous diversity of wildlife habitat, numerous rare species, and intact coastal and estuarine ecosystems of global significance such as those at Plum Island, Sandy Neck, and on outer Cape Cod.

Beaches and dunes are highly dynamic habitats that are continuously reshaped by wind and water. A wide variety of rare and common animal species use these habitats, including habitat specialists such as the Least Tern, Piping Plover, and American Oystercatcher. Beaches serve as foraging areas for vast numbers of migratory shorebirds, and provide habitat for Gray Seals, tiger beetles, and numerous other species. Dunes provide important nesting habitat for Diamondback Terrapins, and are used by several rare insect species. Barrier beach ecosystems include a mosaic of open areas, woodlands, shrublands, and small wetlands.

Estuaries contain a mix of important habitats. Salt marshes and associated tidal flats comprise some of the most productive ecosystems on earth. The salt-tolerant vegetation of the salt marsh community provides the basis of complex food chains in both estuarine and marine environments. Subtle differences in elevation provide a diversity of habitats including low marsh, high marsh, subtidal and intertidal flats, and tidal creeks. Brackish and freshwater tidal marshes and swamps, along with coastal salt ponds, also occur along the Massachusetts coast and provide critically important habitats.

Many animals use the abundant resources of salt marshes, tidal flats, and other estuarine systems including migrating and overwintering waterfowl and shorebirds, such as Snowy Egrets, and habitat specialists such as the Saltmarsh Sharp-tailed Sparrow. Estuaries provide wintering areas for Black Ducks and other species, and staging areas used by species such as Greater Yellowlegs in preparation for migration.

Dunes are a globally rare natural community.

Salt marshes are highly productive and important to coastal and marine biodiversity.

These rich ecosystems not only support numerous rare and common species, but also absorb storm surges, thus protecting inland infrastructure (roads, houses, and other property) as well as fresh groundwater supplies.

Coastal ecosystems face several significant threats. Ongoing development can result in destruction and fragmentation of coastal ecosystems and contributes pollutants that significantly diminish the health of estuarine ecosystems. Coastal habitats are also particularly vulnerable to the potential impacts of climate change. Sea-level rise in coming decades is expected to inundate low-lying salt and brackish marshes, while increased storm intensity is likely to erode beach and dune systems. Increased storm intensities and rapid sea-level rise in combination with the elimination of natural dynamics by jetties, seawalls, and other structures may undermine the ecological function of many coastal ecosystems.

BioMap2 includes 109,000 acres of Core Habitat for more than 40 rare or uncommon coastal species including Piping Plovers, Diamondback Terrapins, and coastal plants such as Oysterleaf. Coastal natural communities are also mapped as Core Habitat representing more than 40,900 acres of salt marsh and dune ecosystems, as well as tidal marshes and flats, beach strands, salt ponds, and coastal woodlands. Buffering uplands that allow coastal systems to adapt to sea-level rise account for 34,500 acres of Critical Natural Landscape. Many of these components overlap. A total of 181,000 acres of coastal ecosystems are included in *BioMap2*, of which 63% is currently unprotected.

Coastal natural communities on the North Shore of Massachusetts.

EXAMPLES OF FRESHWATER WETLAND NATURAL COMMUNITIES IN *BIOMAP2*

Conifer Swamps: Atlantic white cedar, spruce-fir, and spruce-tamarack swamps

Hardwood Swamps: Red maple, black gum, and black ash swamps, and floodplain forests

Marshes and Meadows: Emergent marshes and wet meadows

Peatlands: Fens, bogs, and highbush blueberry thickets

Shrub Swamps: Buttonbush, alder, blueberry, and winterberry swamps

Pond shores: Calcareous and coastal plain pond shores

Riverside: Mudflats and high-energy riverbanks

FRESHWATER WETLANDS: CONCENTRATIONS OF RARITIES, ESSENTIAL HABITAT

Freshwater wetlands are productive ecosystems that support high biodiversity, including unique plant communities and many animal species that are dependent on wetlands for various life cycle needs. Wetlands also serve critical ecosystem functions: they capture heavy rains and help prevent flooding downstream, absorb greenhouse gases from the atmosphere, and store and purify groundwater. Wetlands are extremely important components of the Massachusetts landscape; however, they are limited in extent, covering only about 450,000 acres (less than 10%) of the state. Despite protection by state and federal regulations, historical wetland destruction, encroaching development, habitat fragmentation, unsustainable water withdrawals, pollution, invasive species, and climate change all threaten the ability of wetlands to support biodiversity and to continue to function effectively.

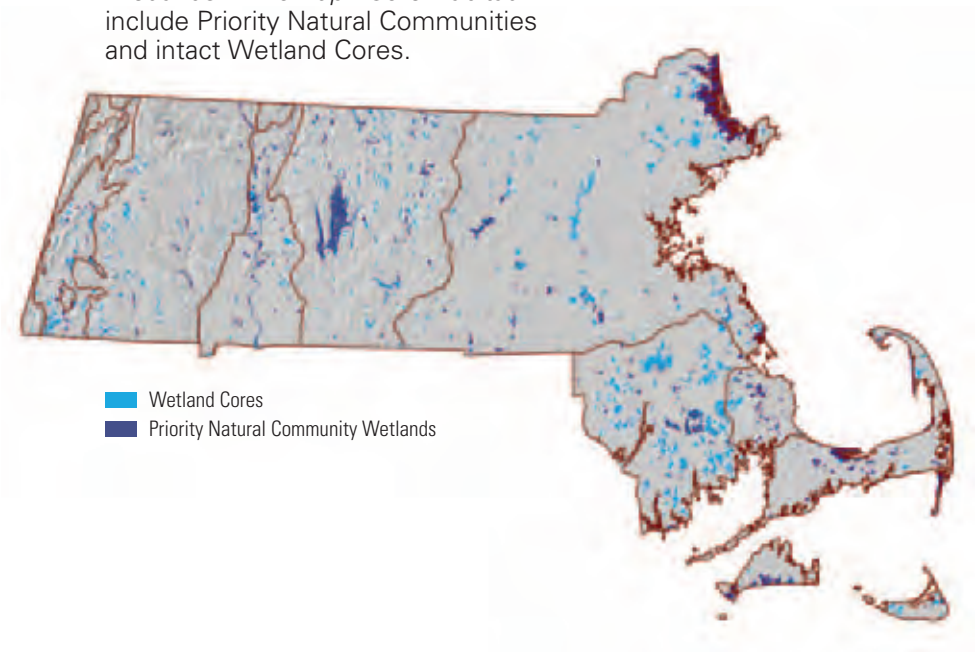
To capture the large suite of plant and animal species that are dependent on wetland ecosystems, *BioMap2* includes a wide range of wetlands as Core Habitat. Extensive habitats are identified for many rare wetland species, including Blue-spotted and Jefferson Salamanders, American Bitterns, and many others. *BioMap2* also includes a wide variety of wetland natural communities, including types such as Atlantic White Cedar Swamps that are more abundant in Massachusetts than in any other state in the Northeast. Several wetland types identified as Core Habitat support a phenomenal number of rare species, including Coastal Plain Pond Shores, which are unique habitats that depend on naturally fluctuating groundwater levels, and Calcareous Fens, which are largely restricted to the lime-rich soils of the Housatonic Valley. Clusters of Vernal Pools are also included as Core Habitat, because populations of Vernal Pool species have greater likelihood of persistence in settings that allow individuals to move among multiple breeding pools.

An intact wetland along the Dead Branch in Chesterfield.

In addition to wetland species habitats and priority natural communities, the most intact wetlands in each of the state's ecological settings were included as Core Habitat. These Wetland Cores are most likely to sustain diverse wetland species and important wetland functions as climate change and other stressors play out over the coming years.

In *BioMap2* Core Habitat, over 92,000 acres of intact freshwater wetland ecosystems are mapped as Wetland Cores, of which 49% remain unprotected. Sixteen thousand five hundred acres of 32 different Priority Natural Community wetland types are also mapped as Core Habitat, although some overlap with the Wetland Cores. Currently, 47% of these unique natural communities is unprotected. Additional wetlands are included in *BioMap2* as vernal pool clusters and habitat for rare and uncommon species, and within Forest Cores, aquatic habitats, and Landscape Blocks. Upland buffer lands, integral to wetland function and resilience, are mapped as Critical Natural Landscape.

Wetlands in *BioMap2* Core Habitat include Priority Natural Communities and intact Wetland Cores.



Moose *(Alces alces)*

Green Heron *(Butorides virescens)*

Spoonleaf Sundew *(Drosera intermedia)* is one of many unique plants found in bog communities.

Costal plain pondshore

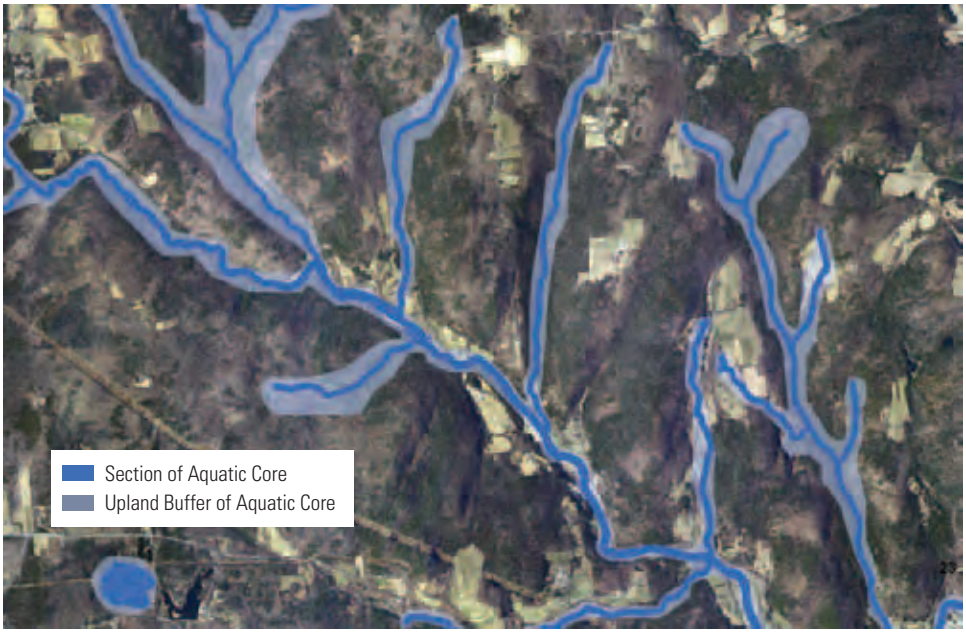
Connecticut River

AQUATIC HABITATS: PROTECTING FRESHWATER BIODIVERSITY

Massachusetts is home to a wide variety of lakes, ponds, rivers, and streams. From small streams that cascade down the steep hills in western Massachusetts, to the powerful Connecticut and Merrimack Rivers, to the low-gradient meanders of the Taunton River in southeastern Massachusetts, the streams and rivers of the Commonwealth provide habitat for numerous species. Similarly, lakes and ponds vary from the mineral-laden hard-water ponds in the Berkshires to the sandy shores of globally significant Coastal Plain Ponds along the coast. Massachusetts waterways have been the lifeblood of Massachusetts' ecology and economy for centuries, supplying power, food, drinking water, and recreational opportunities. Yet pollution, water withdrawal, and habitat fragmentation have long threatened the integrity of aquatic habitats.

Together, these aquatic systems support a great diversity of species, including numerous fish, aquatic plants, freshwater mussels, crayfish, snails, aquatic insects, and more. Some of these species are quite rare, such as the Endangered Dwarf Wedgemussel and the Threatened Lake Chub, while others such as the Eastern Brook Trout are important for the high quality habitat types they occupy and the recreational opportunities they provide. Coastal rivers support fish that migrate between salt and freshwater. And rivers and streams are integrally linked to the floodplain wetlands along their borders, defining dynamic ecosystems and irreplaceable habitat.

BioMap2 Core Habitat includes 220,493 acres, spread over 2,600 river miles, of rivers, streams, water bodies, and floodplains, which support rare and uncommon fish, mussels, and other species. Additional rivers, streams, lakes, and ponds are included in *BioMap2* as components of Wetland Cores, Forest Cores, and Landscape Blocks. Crucially important upland buffer lands are mapped as Critical Natural Landscape.



Habitat that supports aquatic Species of Conservation Concern.

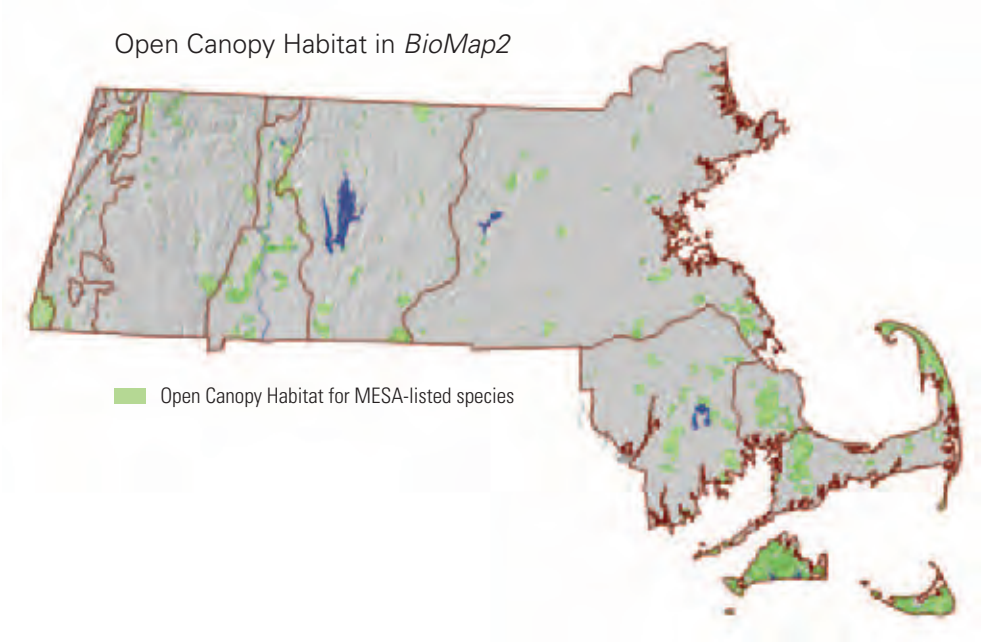
Westfield River

OPEN CANOPY HABITATS: ISLANDS OF REGIONALLY AND GLOBALLY SIGNIFICANT BIODIVERSITY

A remarkable suite of barrens, heathlands, shrublands, grasslands, cliffs, balds, talus slopes, and other nonforested upland natural communities occurs in Massachusetts, supporting numerous rare or uncommon species. These communities typically occur on drought-prone sandy or rocky sites with shallow nutrient-poor soils. Many of these communities also experience periodic disturbance from fire, salt spray, frost, or other natural or human disturbances. The combination of harsh site conditions and repeated disturbance helps to maintain these early successional communities and species within a predominantly forested landscape.

Many rare species of insects, birds, and plants occur in open habitats such as Sandplain Grasslands, Heathlands, and Pitch Pine-Scrub Oak barrens, particularly in southeastern Massachusetts, Cape Cod, and the Islands. Recent studies have also documented significant populations of declining species such as Whip-poor-wills and Hognose Snakes in sandplain communities. Despite their critical importance for biodiversity and as aquifer recharge areas, numerous sandplain communities have been lost to development and several key sites remain unprotected. In addition, many rare and characteristic species are threatened by the dramatic, but understandable, reduction in wildfire in recent decades. Conservation of the remaining natural communities requires not only protection from development but also careful long-term stewardship.

Fifteen distinct open canopy natural community types, comprising 21,000 acres, were mapped for *BioMap2* Core Habitat, 32% of which is unprotected. As these communities are regionally or globally rare systems that provide habitat for many rare or uncommon species, their protection and stewardship will help to conserve critically important islands of biodiversity.



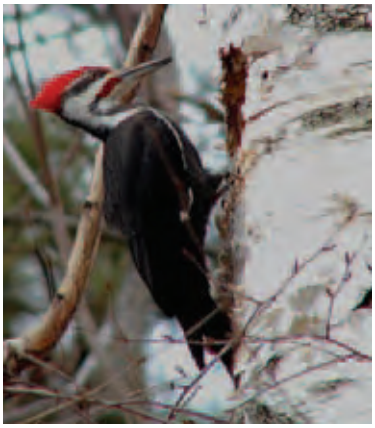
Barrens Buckmoth *(Hemileuca maia)*, Special Concern

Pine barrens in southeastern Massachusetts

Barrens Tiger Beetle *(Cicindela patruela)*, Endangered

Rock outcrop on Mount Tom, Massachusetts

Forests blanket the hills and valleys of the Berkshire Plateau in western Massachusetts.



Pileated Woodpecker *(Dryocopus pileatus)*

FORESTS: THE FOUNDATION OF NEW ENGLAND'S LANDSCAPE

Forests are the dominant vegetation type in the eastern US, and Massachusetts has nearly three million acres of various forest types. The higher elevations of western Massachusetts support Northern Hardwood forests dominated by birch, beech, and maple, while central and eastern Massachusetts are characterized by Central Hardwood forests, predominantly oak and hickory mixed with pine and hemlock. The Commonwealth's extensive forests provide valuable habitat for a wide range of woodland plants and animals. In addition, forests serve critical ecological and societal functions such as filtration of drinking water, absorption of greenhouse gases, absorption and retention of heavy rains thereby reducing flooding, provision of forest products such as wood and paper, and opportunities for recreation.

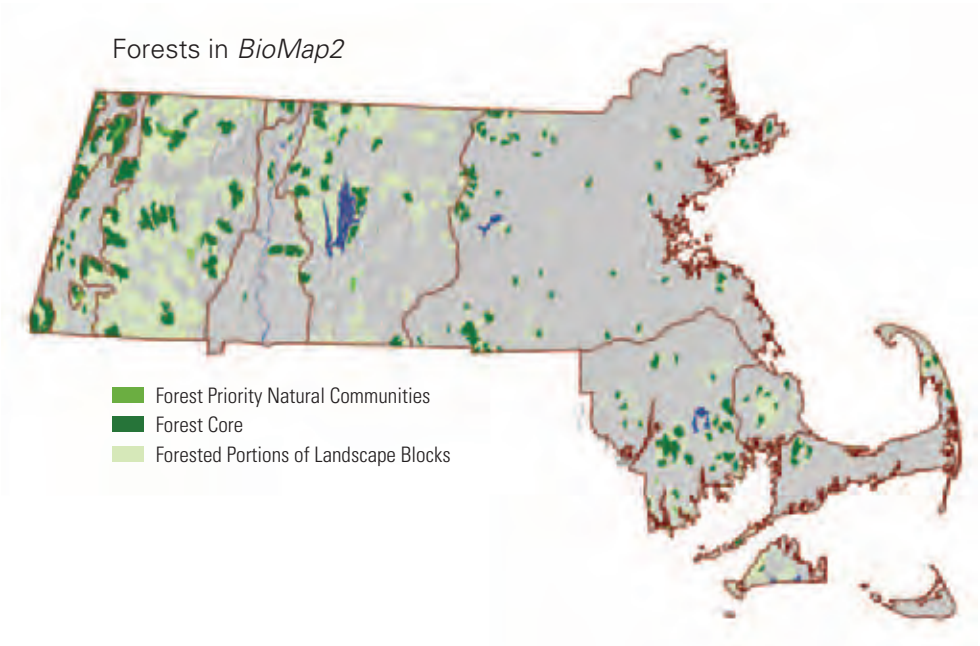
Forest interior habitat—identified in *BioMap2* as Forest Core—is widely recognized as critically important for species sensitive to forest fragmentation and is becoming increasingly scarce in highly populated regions of the country like Massachusetts. Forest interior habitats are the areas least impacted 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. Forest interior habitats also support a wide range of native plants, animals, and ecological processes sensitive to other edge effects such as noise and light pollution from roads and development, invasive species establishment, and alterations to wind, heat, and other climate variables.

Within the forests of Massachusetts, several uncommon natural communities are found in uncommon settings, such as on marble bedrock, at high elevations, or near the coast. An important example is Rich Mesic Forest, found on moist, nutrient-rich sites that support a high diversity of plant species including abundant forest wildflowers (spring ephemerals) such as Dutchman's Breeches, Wild Leek, and Blue Cohosh. Yellow Oak Dry Calcareous Forests occur on marble bedrock in western Massachusetts and also support unique species assemblages. Spruce-fir forests occupy the highest elevations in the state and are thought to be highly vulnerable to warming temperatures associated with climate change.

For *BioMap2*, 325,000 acres of the most intact forest interior habitats across Massachusetts are identified as Forest Core, representing about 10% of the state's forests. The largest examples are in the Taconic Mountains, Berkshire Plateau, and northern portions of the Worcester Plateau, while smaller but significant areas are identified in the major lowland valleys and in eastern Massachusetts. Thirty-eight percent of the total Forest Core area remains unprotected; these areas are high priorities for land protection since they provide important habitat for forest interior and other species. Forest Cores are complemented by, and occasionally overlap with, 20 different forested natural community types, which support 9,300 acres of unique and irreplaceable plant and animal assemblages, 28% of which is unprotected. Surrounding Forest Cores and other habitats, Critical Natural Landscape identifies extensive and predominantly forested Landscape Blocks. Combined, *BioMap2* forests total 1,232,000 acres, 53% of which is unprotected.

Rich mesic forests support diverse and abundant spring wildflowers, including Trout Lily *(Erythronium americanum).*

Scarlet Tanager *(Piranga olivacea)*



Bobcat *(Lynx rufus)*

LANDSCAPES: THE BIGGER PICTURE

BioMap2 is designed to prioritize Species Habitats, Natural Communities, and intact ecosystems to guide land protection and stewardship for biodiversity. Biodiversity conservation also requires protecting intact landscapes at larger scales. Landscapes are defined as mosaics of forests, wetlands, rivers, shrublands, and other habitats, from valley bottoms to ridgetops. Intact landscapes provide an aggregation of contiguous habitats and connectivity among them, to support the long-term viability of wildlife populations and to help maintain natural ecosystem processes.

Large intact landscapes, represented in *BioMap2* as Landscape Blocks, provide diverse habitats at a scale necessary to sustain healthy populations of wide-ranging species like Moose, Black Bear, and Bobcat. These animals travel great distances and have large home ranges (the area where an animal lives and travels over the course of a year). The integrated patchwork of wetlands, uplands, and rivers that are found in unfragmented landscapes allows animals to move freely among habitats, supporting daily movements, migration, dispersal, and colonization of new habitats. For example, Spotted Turtles, Blanding's Turtles, and Fishers all move among upland and wetland habitat types throughout the year. Intact landscapes also facilitate shifts in the geographic distribution of species, a process that is likely to accelerate in response to climate change in the coming decades.

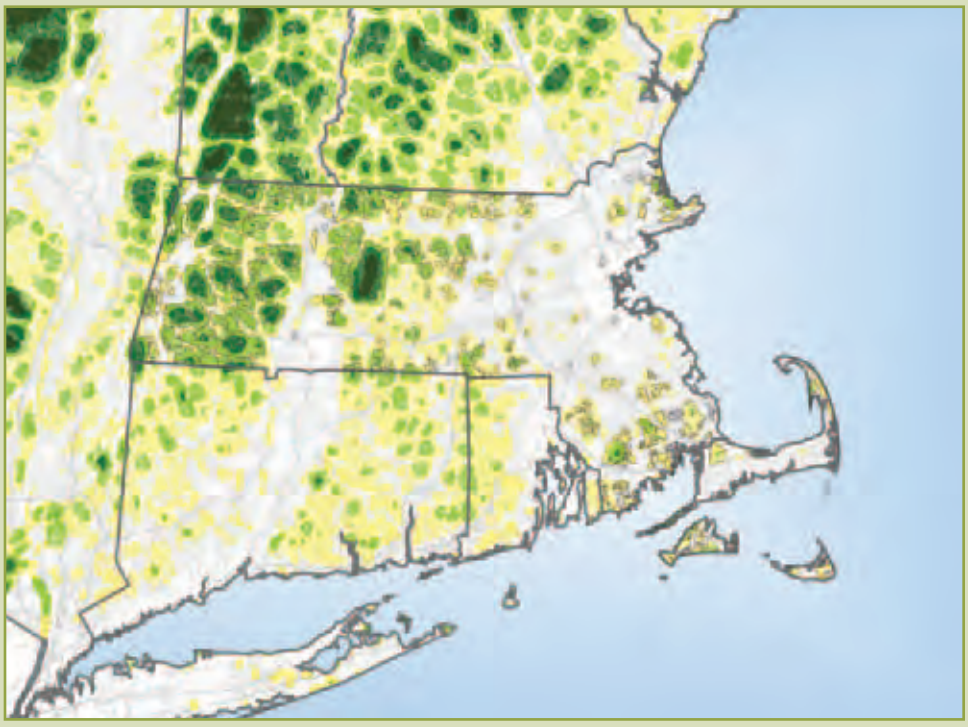
In contrast to intact landscapes, landscapes fragmented by roads and development result in smaller and more isolated habitat patches, with barriers and resistance to movement. Species that are dependent on intact landscapes avoid developed areas. Direct mortality on roads, combined with indirect impacts of development such as noise, light, pollutants, and invasive species, provide additional hurdles for vulnerable species.

Landscapes also support ecosystem processes and interactions among different habitats, making the whole greater than the sum of the parts. For example, large forested watersheds capture, filter, and gradually supply clean, cool water and nutrients

to our river networks, supporting a wide array of fish, mussels, insects, reptiles, amphibians, and mammals. Intact landscapes also buffer smaller and more sensitive species and natural communities—such as wetlands, vernal pool species, freshwater habitats, and rare ridgetop inhabitants such as Timber Rattlesnakes—from the impacts of roads and development. Landscapes are naturally dynamic, described by some as shifting mosaics. Over time, habitats and ecosystems expand, contract, and shift location across larger landscapes as a result of species interactions, natural disturbances, and climate change. The dynamic nature of landscapes, which can only occur in large intact areas, results in a mosaic of habitat types and patches that in turn support a wide array of species. For example, disturbances such as blowdowns, ice storms, tornados, and other weather events result in patches of young forest embedded within larger patches of older forest. Many species depend on these younger forests for breeding and foraging habitat. Another example of a dynamic natural process is the flooding of low-lying forests resulting from Beaver dams, converting former closed canopy forests into open canopy wetlands.

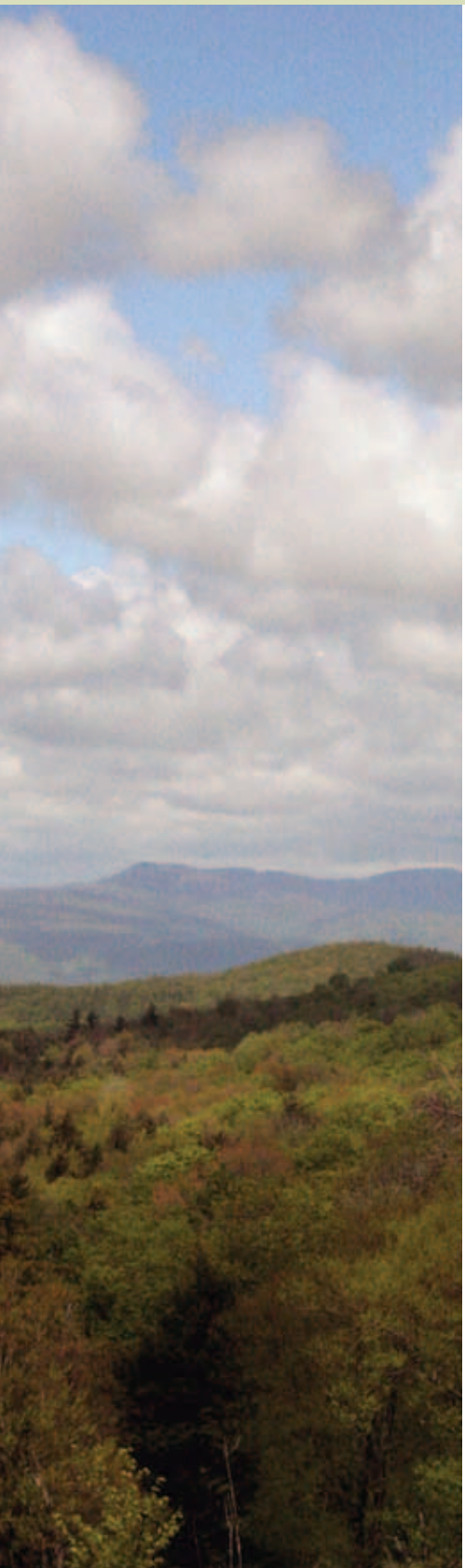
Dynamic landscapes support a diversity of species over time.

Landscape Blocks comprise 1,474,000 acres of *BioMap2* Critical Natural Landscape. The largest Blocks are in rural areas of western Massachusetts, yet significant natural landscapes remain in eastern Massachusetts. Of the total area of Landscape Blocks, 53% are currently unprotected.



BioMap2 Landscape Blocks in the context of a regional assessment of intact landscapes. Because the landscapes and wildlife of Massachusetts are integrally connected to surrounding states, *BioMap2* was developed in the context of regional landscape patterns. Successful biodiversity conservation will require working across state borders.

CHAPTER 6
Achieving Strategic Conservation with *BioMap2*



For more than a century, the importance of land protection and stewardship for securing natural resources, recreational opportunities, wildlife, and biodiversity has been recognized by numerous conservation organizations, public agencies, and dedicated individuals across the Commonwealth. As a result, Massachusetts now has more than 1.2 million acres of land that are protected in perpetuity, 23% of the state's 5.2 million acres. The Commonwealth is by far the largest owner of protected lands in Massachusetts with almost 600,000 acres. Conservation organizations, federal agencies, local and regional land trusts, and numerous individual landowners protect an additional 350,000 acres across Massachusetts. The remaining acreage is protected primarily by the municipalities of Massachusetts.

THE FIRST *BIOMAP*: MAKING A DIFFERENCE

The direct loss of habitat is one of the greatest threats to biodiversity globally, as it is in Massachusetts. Yet well-planned and sited development is an important component of economic and social well-being. The original *BioMap*, produced by NHESP in 2001, provided a guide for proactive land conservation, and in doing so, indicated locations more appropriate for residential and commercial development compatible with conservation.

Public and private conservation agencies and organizations have accomplished a great deal of land protection across the state in the 10 years since the original *BioMap* was developed. Just under 72,000 acres identified as Core Habitat in 2001 have since been protected, as well as 45,000 acres of Supporting Natural Landscape. Combined, this represents approximately 69% of all lands protected by all entities since 2001. The Commonwealth's conservation agencies protected almost 49,400 acres since they were identified in *BioMap*, including 36,400 acres by DFW and 10,100 acres by DCR.

Land protection by the Commonwealth has varied annually since the 2001 release of *BioMap*, with over 16,000 acres protected in 2004, but fewer than 4,000 acres protected per year in 2005 and 2006. Governor Patrick has maintained a strong commitment to land conservation and has provided substantial annual funding for land protection, with the Commonwealth protecting over 16,000 acres in Fiscal Year 2010. Because state funding for land protection and stewardship has been inconsistent, conservation action on the part of individuals and non-government organizations has been crucial over the past decade.

Mount Greylock in western Massachusetts, one of the earliest natural areas protected in the Commonwealth, currently owned and managed by the Department of Conservation and Recreation

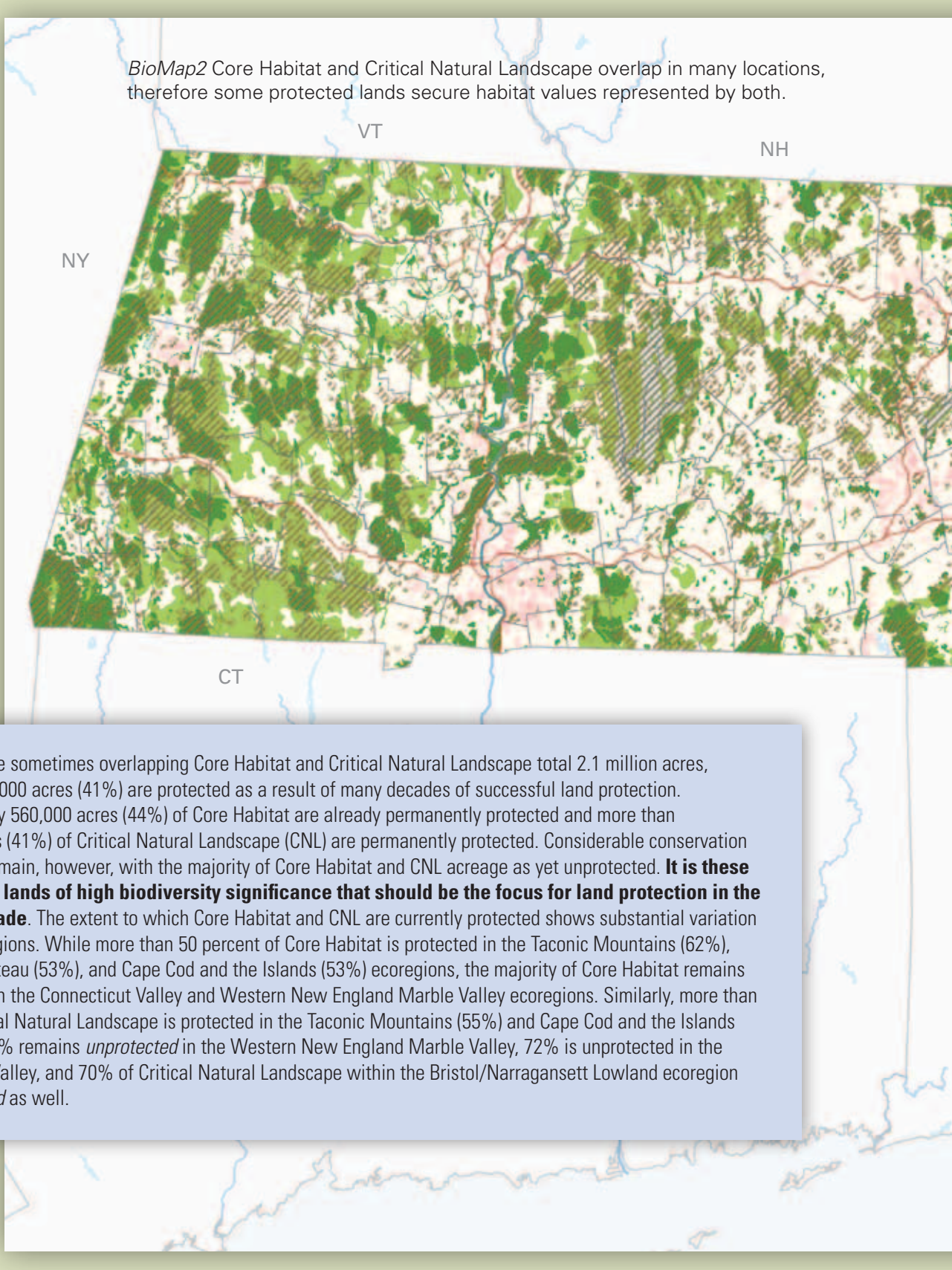
An addition to Mass Audubon's Burncoat Pond Wildlife Sanctuary in Spencer, MA was made possible through a cooperative project with the Town of Spencer and EOEEA.

Unfortunately, significant areas of original Core Habitat that were unprotected have been lost to development since 2001. At least 11,000 acres that had been identified as Core Habitat in 2001 experienced subsequent development and fragmentation, and are therefore excluded from Core Habitat in *BioMap2*. Even more alarmingly, almost 27% and 42% of the original *BioMap* Core Habitat and Supporting Natural Landscape, respectively, are within 100 meters of development created since 1999. This represents a significant loss of critical habitats for biodiversity during recent years.

Some Core Habitat in the first *BioMap* (a) has since been developed and is therefore not included in *BioMap2* (b).

a b

BIOMAP2: MAKING GAINS, BUT MORE WORK TO BE DONE



BioMap2 Core Habitat and Critical Natural Landscape overlap in many locations, therefore some protected lands secure habitat values represented by both.

Combined, the sometimes overlapping Core Habitat and Critical Natural Landscape total 2.1 million acres, of which 861,000 acres (41%) are protected as a result of many decades of successful land protection. Approximately 560,000 acres (44%) of Core Habitat are already permanently protected and more than 700,000 acres (41%) of Critical Natural Landscape (CNL) are permanently protected. Considerable conservation challenges remain, however, with the majority of Core Habitat and CNL acreage as yet unprotected. **It is these unprotected lands of high biodiversity significance that should be the focus for land protection in the coming decade**. The extent to which Core Habitat and CNL are currently protected shows substantial variation among ecoregions. While more than 50 percent of Core Habitat is protected in the Taconic Mountains (62%), Berkshire Plateau (53%), and Cape Cod and the Islands (53%) ecoregions, the majority of Core Habitat remains *unprotected* in the Connecticut Valley and Western New England Marble Valley ecoregions. Similarly, more than 50% of Critical Natural Landscape is protected in the Taconic Mountains (55%) and Cape Cod and the Islands (52%), but 77% remains *unprotected* in the Western New England Marble Valley, 72% is unprotected in the Connecticut Valley, and 70% of Critical Natural Landscape within the Bristol/Narragansett Lowland ecoregion is *unprotected* as well.

HOW FINE A LINE?

In identifying the most crucial areas for conservation, the development of *BioMap2* required the drawing of lines to delineate Core Habitats and Critical Natural Landscape. However, it is important to remember that, on the ground, the actual edges of mapped habitats, natural communities, and intact ecosystems are often not as abrupt as a single line, and habitat value and ecosystem processes often extend beyond the areas delineated. Furthermore, habitat boundaries are not static and, with climate change, may rapidly shift in the future. The line work shown in *BioMap2* is derived from state-of-the-art scientific methodology and represents the best available data on habitat boundaries today.

PUTTING *BIOMAP2* TO USE

BioMap2 is based on a combination of 30 years of rare species and natural community data from the Natural Heritage & Endangered Species Program, habitat mapping for additional wildlife species, and applications of spatial models to identify intact ecosystems and landscapes across the state. Like the original *BioMap*, it is designed as a tool for prioritizing land conservation and stewardship to protect and conserve the native biodiversity of Massachusetts.

Coastal habitat for rare species is protected at The Trustees of Reservations' Crane Beach.

The original *BioMap* included Core Habitats as the highest priority for protection, and Supporting Natural Landscape areas as additional targets for protection in order to help maintain the viability of the Core Habitats. *BioMap2* uses a targeted approach to explicitly include a more comprehensive assemblage of native biodiversity. It specifically addresses both coarse and fine filter elements of biodiversity and incorporates strategies to help ecosystems adapt to the impacts of climate change. These innovations in the creation of *BioMap2* influence its application. **In *BioMap2*, the Core Habitat and Critical Natural Landscape are complementary and overlapping, and were delineated based on separate criteria. Each represents a different scale of biodiversity in Massachusetts, yet the protection of both is important to conserve the full suite of biodiversity in the state**.

Core Habitats in *BioMap2* are based on rare species habitat mapped from actual observations, habitat for wildlife of conservation concern, exemplary natural communities, least disturbed wetlands, forest interior habitat, clusters of Potential Vernal Pools, and other conservation targets. These delineations are based on both substantial high-quality field data and an understanding of species habitat requirements—the fine filter approach—and interpretation of land cover and land use data representing the distribution of ecosystems and patterns of development that affect them—the coarse filter approach. They therefore represent the areas in which land protection and stewardship will contribute most significantly to the conservation of **specific** elements of biodiversity.

As the name suggests, the Critical Natural Landscape areas are critically important to conserving a **broad** range of biodiversity, delineated at a larger scale than the Core Habitats, and the patterns and processes that support it—the coarse filter approach at a larger scale. Critical Natural Landscapes are intended to capture the largest and most intact natural blocks across the Commonwealth in order to support the long-term viability of both wide-ranging organisms and entire populations of species. These areas minimize impacts from development on natural systems, allow connectivity among habitats, and provide adequate area for natural processes such as periodic severe weather events, which result in complex patterns of forest composition and structure that support diverse species.

New England Bluet *(Enallagma laterale)*, Special Concern

Land protection is a crucial tool to protect the biodiversity values defined by *BioMap2*; however, it will not be possible to protect this extensive an area in the near term. Thoughtful land use helps safeguard these areas and supports human communities that rely on our state's natural resources. In addition to differences in scale, Core Habitat and Critical Natural Landscape differ in the amount of human impact each can tolerate and still retain their important habitat values. Simple land protection may be the best conservation strategy within most areas of Core Habitat, but extensive Landscape Blocks (found in the Critical Natural Landscape) will support moderate levels of compatible human use such as timber harvesting in working forests and specific agricultural practices. This allows more flexibility in the types of land protection tools available for preserving biodiversity within Critical Natural Landscape. For example, working forest easements may be very useful for protecting CNL, but might not be ideal for some parcels identified as Core Habitat.

The on-line *BioMap2* website, www.nhesp.org (under the Land Protection and Planning tab), will allow the user to view these layers separately, to tease apart many inputs to Core Habitat and Critical Natural Landscape, and determine which areas best meet the users' conservation or management objectives.

Each conservation group, whether a local land trust, a statewide nonprofit, a government agency, or municipality, has its own goals and criteria for conservation. Prioritization for protection among Core Habitat areas and Critical Natural Landscapes will depend on the overall goals and objectives of each conservation organization. For example, an organization intent on protecting vernal pool habitat could target areas within Core Habitat delineated for that specific habitat type. An organization intent on maintaining landscape level processes, such as a watershed conservation association or town-based conservation group, may target Critical Natural Landscape. *BioMap2* is a valuable tool to allow individual conservation entities to further their specific conservation goals.

Land protection for many Core Habitat and Critical Natural Landscape areas can also be guided by existing conservation ownership, organization resources, and the strength of working partnerships. For example, if the state owns 600 acres of a 1,000-acre Core Habitat area, the protection of the remaining portions of the Core Habitat may become a priority for the state. Or, an area of Critical Natural Landscape adjoining properties already protected by a conservation organization may be a high priority for protection to provide connectivity for wildlife. Larger and/or more expensive areas may be better candidates for protection by statewide nonprofit organizations, by state or federal agencies, or by coalitions and partnerships. Large complexes of Core Habitat and Critical Natural Landscape areas may require multiple acquisitions over a number of years through the collaborative efforts of a variety of local and regional conservation entities.

The Nature Conservancy protected Gobble Mountain, in Chester, abutting extensive protected lands.

Over 200 acres of Mt. Watatic, including the summit, was purchased in 2002 through a partnership of the Ashby Land Trust, the Ashburnham Conservation Trust, the towns of Ashby and Ashburnham, Massachusetts Division of Fisheries and Wildlife, and Massachusetts Department of Conservation and Recreation.

PROACTIVE NOT REACTIVE

BioMap2 can contribute to improved conservation planning, increased coordination among conservation groups and government officials, and more effective biodiversity conservation. Often, by necessity, land conservationists find themselves reacting to immediate crises, whether the imminent construction of 50 houses in a favorite forest or a family needing to sell its woodlands to settle an estate. Using *BioMap2* to develop and target protection priorities proactively, before a crisis emerges, can facilitate more efficient use of limited conservation dollars.

In addition to biodiversity protection, there are many other reasons to protect land from development, such as protecting drinking water supplies, providing recreational opportunities, and preserving aesthetic and cultural landscapes. Coupling biodiversity protection efforts with these concerns strengthens public support for land conservation overall and develops broader and more effective constituencies. Incorporating *BioMap2* Core Habitats and Critical Natural Landscapes into the next update of municipal Open Space and Recreation Plans, for example, is an opportunity to discover overlapping reasons to focus on particular areas.

STEWARDSHIP AND RESTORATION OF BIODIVERSITY

Although the economic pressure to develop natural land in parts of Massachusetts has slowed recently, land protection continues to remain an important focus for many conservation organizations, agencies, and municipalities. However, management of land and water, and ecological restoration of habitats are also critical components of biodiversity conservation. Some species require active management by humans for their habitats to persist, either because the natural ecological processes that support biodiversity have been disrupted or because humans have encroached upon and altered the habitats of native species.

LEGAL PROTECTION OF BIODIVERSITY

BioMap2 presents a powerful vision of what Massachusetts would look like with full protection of the land that supports our breadth of biodiversity. But it is a prioritization tool, not a simple map of all undeveloped land in the state. To achieve meaningful prioritization, a few populations of rare species presently protected under the Massachusetts Endangered Species Act (MESA) were deemed by the Natural Heritage & Endangered Species Program as somewhat less likely to survive over the long term than other populations; some of these potentially less viable populations were not included in *BioMap2*.

However, regardless of our current estimate of their potential future viability, all documented populations of state-listed rare species have, and will continue to have, full legal protection under MESA and the Wetlands Protection Act (WPA) regulations. *BioMap2* is a conservation planning tool and does not in any way supplant Natural Heritage's Priority and Estimated Habitats maps, which have regulatory significance under MESA and WPA. With our rapidly changing landscape, global climate change, and continued scientific research, some populations of rare species outside of current *BioMap2* areas may ultimately prove just as important as those within *BioMap2*.

Widespread use and implementation of *BioMap2* as a proactive tool to help maximize biodiversity protection will take us further toward this vision, but meanwhile, the MESA and rare wildlife component of the WPA exist to protect rare species and their habitats within Massachusetts today.

In the past, dynamic ecosystems and important natural disturbances, such as flooding, storms, or wildfires, created conditions many different species were dependent on. With the current density of human development in the state, formerly dynamic systems are now constrained by roads, houses, and other infrastructure, rendering the landscape more static and biodiversity less resilient. But by restoring ecological processes, habitat management can often restore the specific conditions required by different species or natural communities. For example, on the Montague Plains, prescribed burning and selective timber harvesting have been used for 12 years to restore and maintain habitat for a wide variety of species dependent on shrubby Pitch Pine/Scrub Oak barrens habitat. By carefully allowing fire back into a globally rare fire-dependent system that has undergone fire suppression for decades, active management is bringing back populations of rare species that were nearly extirpated from this area.

Sora *(Porzana carolina)*

Other challenges to biodiversity, including the introduction of invasive species, habitat fragmentation from roads and dams, and alterations to stream flow, also require active management. Innovative strategies are necessary to abate these problems. The Massachusetts Division of Ecological Restoration addresses threats to aquatic, coastal, and other ecosystems, and provides technical support to local governments and private citizens for restoration efforts. For important rivers such as the Taunton and Westfield, assessments of the impact of roads on river continuity, followed by collaborative efforts to remove dams and improve road-stream crossings, have reconnected fragmented aquatic habitat. Removal of tidal restrictions can enhance salt marsh habitat, and many organizations and agencies are working to restore adequate flow to support healthy rivers. One partnership among the Massachusetts Department of Transportation, NHESP, and DFW is a project to monitor animals, especially rare species, killed crossing roadways, so that in the future road construction can be designed to facilitate wildlife crossings. At various scales, many organizations are working to prevent the introduction and spread of invasive plants, insects, and pathogens into natural systems to maintain viable habitat and ecosystems. Biologists at the Natural Heritage and Endangered Species Program are available to work with organizations and municipalities to develop management plans for areas needing habitat management and ecological restoration for the conservation of state-listed or target species.

BIOMAP2: INTO THE FUTURE

BioMap2 builds on the original *BioMap*, *Living Waters*, and the *State Wildlife Action Plan* to prioritize and guide biodiversity conservation in Massachusetts in the context of continued development and the anticipated effects of climate change. It is based on the latest survey information and spatial analyses available, and it identifies the areas of highest conservation value for a variety of biodiversity elements. Attributed online data layers will help conservation organizations proactively target areas to meet specific conservation goals, from individual species conservation to the stewardship of interconnected landscapes. Working together, with *BioMap2* as a roadmap, we can protect the natural heritage of Massachusetts for years to come.

Intensive efforts over the past several years have restored extensive grassland habitat at Frances Crane Wildlife Management Area on Cape Cod.

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