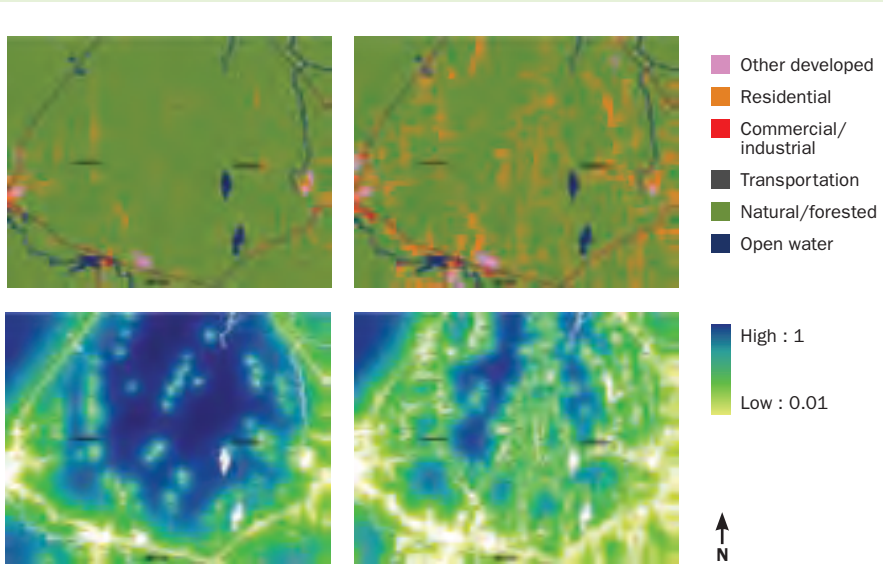
CHAPTER 3: QUANTIFYING ECOLOGICAL IMPACT

Goal of Analysis

Quantifying the footprint of development is an important first step in identifying its impact on the nature of Massachusetts. However, ecological impacts to habitat and wildlife extend beyond the lawns, roads, and buildings that make up the residential, commercial, and industrial footprint. We know that the ecosystem surrounding a home or building will be impacted by increased edge effects, disruption of ecological processes, changes in microclimate, and hydrology. Using an exciting new analytical tool, we investigated impacts that extend beyond the footprint of development into the larger ecosystem and examined how they vary across the state.

The CAPS model was run for 1971, 1985, 1999, and 2005 using the MassGIS Land Use/ Land Cover data sets. This made it possible to investigate changes in the ecological integrity of the Massachusetts landscape over the past 35 years.

Figure 3.1: Land Use/Land Cover data for 1971 and 2005 and also the IEI results for 1971 and 2005 for a portion of the towns of Townsend and Pepperell.



WHAT IS CAPS?

In order to investigate the ecological impacts of development in Massachusetts, Mass Audubon partnered with researchers at the Department of Natural Resources Conservation at the University of Massachusetts, Amherst. Kevin McGarigal, Scott Jackson, Brad Compton, and Kasey Rolih have developed the Conservation Assessment and Prioritization System (CAPS) model. CAPS is a spatial model designed to assess the ecological integrity of lands and waters across relatively large geographic extents (e.g., all of Massachusetts). Ecological integrity can be thought of as the ability of an area to support plants and animals and the natural processes necessary to sustain them over the long term. The CAPS model presumes that by conserving intact areas of high ecological integrity, we can conserve most (but not necessarily all) species and ecological processes.

The CAPS model creates a grid over the state of Massachusetts, and calculates the "index of ecological integrity" (IEI) for each cell of the grid based on eight different ecological factors. These factors include habitat loss; microclimate alterations; impacts from domestic predators such as cats and dogs; impacts from edge predators such as raccoons, blue jays, and cowbirds; non-native invasive plants; non-native invasive earthworms; connectedness of the landscape; and similarity of each point to the surrounding landscape. The resulting map is a computer model of the ecological function of the landscape. Like all computer models, it has its limitations, but it also speaks powerfully to very real impacts in landscape-level ecological function and integrity.

One limitation of CAPS is that it does not consider explicitly rare and endangered species that are essential components of the biodiversity of Massachusetts. The great biodiversity value of southeastern Massachusetts and the importance of coastal ecosystems to migratory shorebirds are critical to conservation in Massachusetts, yet not reflected in the CAPS maps. In addition, land conservation of smaller parcels and in more densely developed areas continues to be an important component of community-focused conservation in Massachusetts, yet the CAPS analysis does not highlight the need for urban ecology and recreation, stormwater mitigation, and water supply protection.

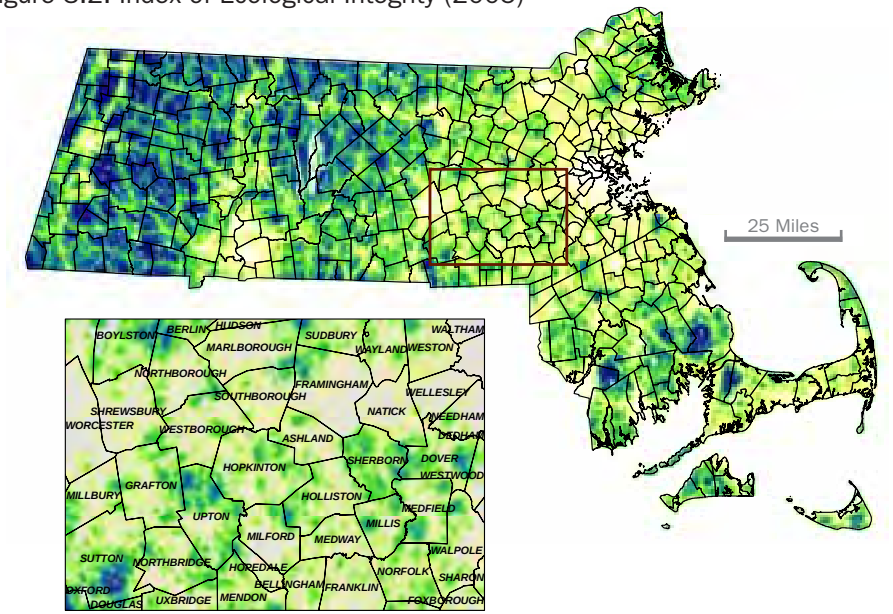
Nonetheless, the CAPS analysis provides an important tool for land conservation prioritization in Massachusetts. The CAPS maps highlight less fragmented areas of high ecological function and show us areas where ecological processes are most intact across the landscape. They also highlight the impact of development on ecosystem function, by graphically showing the effects of fragmentation on large blocks of naturally vegetated land.

In the case of a block of lightly developed land along the Townsend-Pepperell border, development present in 1971 is sufficiently scattered that a large contiguous block of high-integrity natural land persists, as shown in darkest blue in the 1971 CAPS map. Between 1971 and 2005, many individual homes were built along secondary roads within this block. The result is that the one mostly connected block of natural land has now been split into two much smaller strips, and it is evident that both of these blocks do not contain the dark blue areas of high IEI scores. The above information was generated for the entire state and for four years, 1971, 1985, 1999, and 2005. It allows for a detailed look at the changes in ecological integrity that have taken place statewide, across large areas such as watersheds, and down to smaller units of analysis such as towns.

The Patterns of Ecological Integrity

Figure 3.2 represents the 2005 IEI scores for the entire state. This map shows the value of each 30 by 30 meter grid cell. At the statewide scale, intact natural lands can be seen, primarily in western Massachusetts and surrounding the Quabbin Reservoir, but also in southeastern Massachusetts, just south of Worcester, and in some North Shore communities. The power of the CAPS model is that it can be used for analysis at a statewide, regional, or townwide scale.

Figure 3.2: Index of Ecological Integrity (2005)



Between 1971 and 2005, Massachusetts suffered a 23% reduction in its overall ecological integrity. Over the same period, only 8% of the state's land area, or roughly 400,000 acres, was developed. In 1971, the total IEI-acres score for Massachusetts was 2,093,500 IEI-acres while in 2005, it stands at 1,618,000 IEI-acres. Between 1999 and 2005, the statewide total fell by 9%.

The Patterns of Loss

The following section looks at the pattern of loss in ecological integrity in several different ways. Figure 3.3 shows the loss of ecological integrity in a transect running through the state, and then zooms into three clusters of towns. The transect shows that significant reductions in IEI (shown in black, red, orange and yellow) are occurring both in the Sprawl Frontier and beyond. In the east, loss is not as widespread because land is, for the most part, already developed, or protected. In the west, smaller clusters of loss are evident amidst much larger blocks of intact natural land. It is in central Massachusetts, in towns such as Barre, Oakham, Brookfield, and Belchertown, where the impacts of development are visible and widespread, and thus fall in the new Sprawl Danger Zone. While IEI scores in western Massachusetts remain high, the pattern of loss is striking because it is already evident in all towns as scattered impacts that closely follow the existing roads.

IEI-ACRES DEFINED

The Index of Ecological Integrity (IEI) depicts the value of a given point on the landscape relative to others based on its ability to support plants, animals, and the natural processes that sustain them. To facilitate this comparison of one area with another, units called IEI-acres are used throughout CAPS analysis. One IEI-acre is equivalent to an acre of cells—roughly five cells—with a perfect score of 1. One IEI-acre can also be made up of 2 acres of cells each with a score of 0.5.

For example, consider the town of Townsend with a total land area of 21,100 acres. In 1971, Townsend had an IEI score of 12,000, i.e., the sum of the cells in the town's 21,100 acres added up to 12,000 IEI-acres. By 2005, Townsend's score had dropped to 8,700 IEI-acres, which can be thought of as a loss of 3,300 acres of land with high ecological integrity. This loss occurred throughout the entire acreage of the town rather than on just 3,300 acres; but it enables comparison of Townsend with other towns and allows calculation of the change in IEI over time.

Figure 3.3: Loss of ecological integrity between 1971 and 2005, a transect through Massachusetts

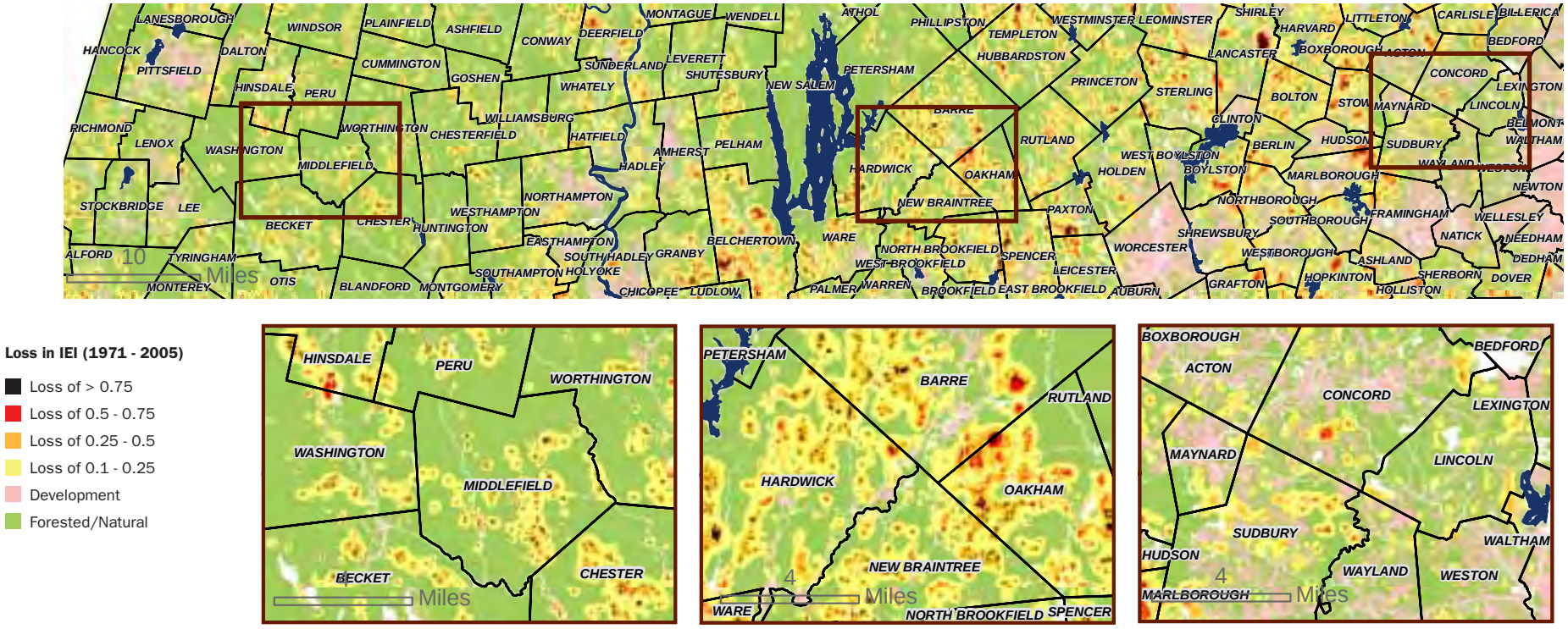
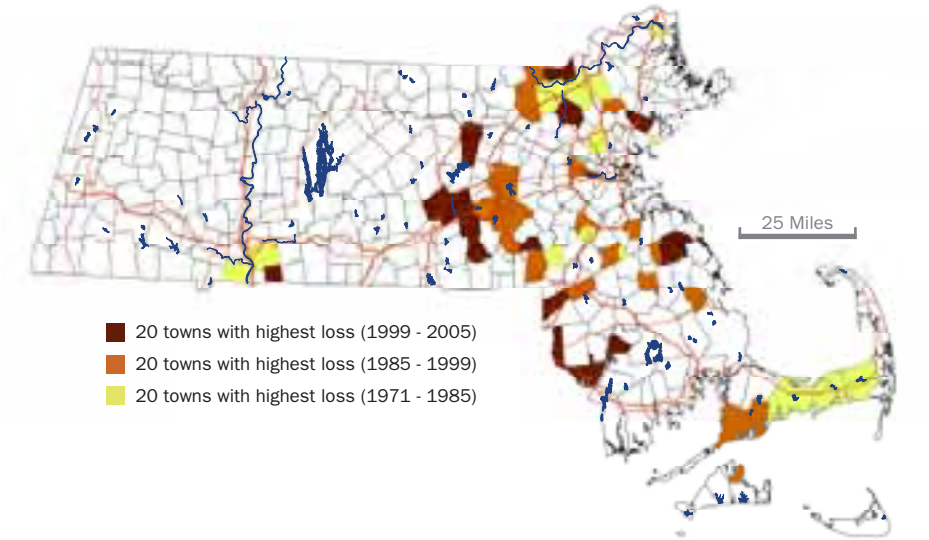


Figure 3.4 shows the 20 communities with the largest loss in IEI values from 1971-1985, 1985-1999, and 1999-2005. This figure mirrors the impact of the Sprawl Frontier very closely. In the 1970s and early 1980s, the highest impacts were seen close to existing urban centers of Boston, Springfield, Lowell/Lawrence, and on Cape Cod. From 1985 to 1999, development along I-495 was clearly having an impact on the ecological integrity of natural lands in these cities and towns. During the most recent time step, the impacts extend beyond I-495 in all directions, toward Nashua, New Hampshire, in the north; toward Worcester in the west; and toward Providence, Rhode Island, in the south. This figure affirms one focus of conservation efforts on the Sprawl Frontier.

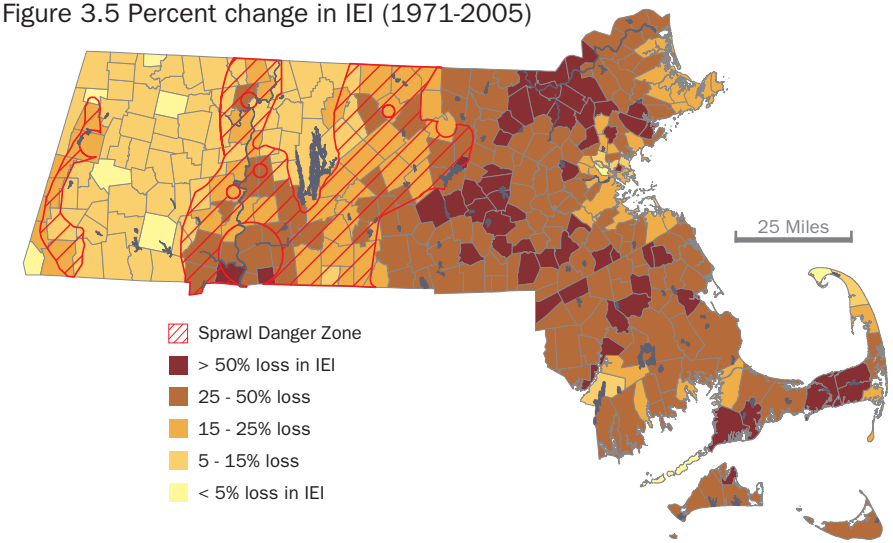
Figure 3.4: Towns with highest loss (percent change) in IEI through time



Historically, *Losing Ground* has focused on recent growth, attempting to highlight the location of the Sprawl Frontier, where the *fastest* development is occurring. However, the next figure shows how the impacts to the natural resources of Massachusetts have begun to accumulate in the towns that lie *beyond* the Sprawl Frontier. Figure 3.5 shows the loss in IEI from 1971 to 2005, and is one of the key figures that spurred the delineation of the Sprawl Danger Zone. More than half of the towns in the state (209) have undergone at least a 25% reduction in their IEI score since 1971; this high impact extends beyond I-495 to I-190, which lies 45 miles inland of Boston. With the exception of a small band of towns southeast of the Quabbin Reservoir, this band of 25 to 50% reduction extends all the way to Springfield, and extends up the Connecticut River valley and into the agricultural towns of Massachusetts. The next lowest range of IEI loss (15 to 25%) creates a solid wall of towns all the way to the Quabbin, and extends from north to south up the entire Connecticut River valley.

The Sprawl Frontier is the *crest* of a wave of development. This analysis shows that the development that occurs *before* the crest, the Sprawl Danger Zone, has already had a significant impact on the ecological integrity of the landscape. There is a band of towns running north-south to the east of the Quabbin Reservoir that has been spared the highest impacts, and these towns deserve attention and resources. In addition, the block of towns west of the Connecticut River, transitioning into the Berkshires, have had the smallest reductions in IEI. As CAPS measures it, these towns contain the lands with the highest ecological value in the state.

Figure 3.5 Percent change in IEI (1971-2005)



LOCAL VS REGIONAL LAND PROTECTION EFFORTS

The CAPS analysis identifies large blocks of land of high ecological value. However, land in much of the state falls in the lower categories of ecological value. In some of these areas, there is not much land left to protect. In towns that have low IEI scores, the ecological value of the land to the town is still high. The ecological services and benefits provided by natural lands in densely developed areas are of great value to individual communities, and additional natural land should be protected. The CAPS model is useful because it suggests ways that local IEI scores could be increased through management of both protected and unprotected land. Activities such as removing invasive plants or minimizing domestic animal/wildlife interactions can improve habitat quality locally. Individual management activities, in addition to focusing on larger reserves and outright land protection, should be part of the overall conservation strategy.

Direct vs Indirect Impacts of Developments

The CAPS analysis provides the opportunity to compare the direct impacts of recent development with the indirect impacts of recent development. Direct impact is the loss in ecological integrity that happens immediately under the footprint of development. Cells that were previously natural and are converted to a home or commercial/industrial building, for instance, will change to a zero value. The direct impacts are calculated by summing up the loss in IEI for all cells of new development. The indirect impacts of development are determined by looking at all of the cells that remain undeveloped. While they remain in a natural state, their values have been altered as a result of their proximity to new development. Figure 3.6 shows the impact of two subdivisions that were recently built. The zones in reddish brown, penetrating significantly into the surrounding forest, had a decrease in the IEI value of at least 50%. The ecological impacts of development extend far *beyond the footprint* of our homes and buildings.

Figure 3.6: Decrease in ecological integrity surrounding new development

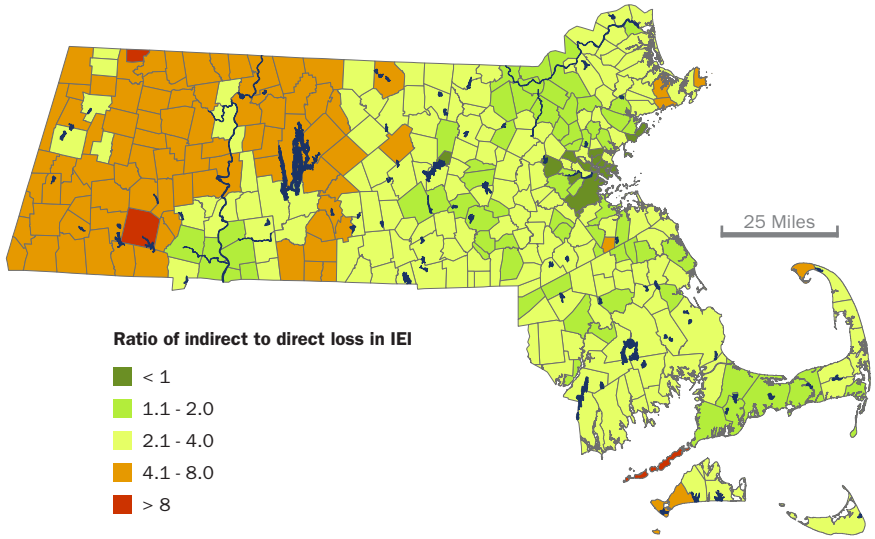
Table 3.1 compares the direct and indirect impacts of development. The indirect impacts of development are three to four times greater than the direct impacts of development. From 1971-2005, the indirect impacts were three times greater than the direct impacts of development.

Table 3.1: Direct and indirect loss in ecological value over time (statewide)

	1971-1985	1985-1999	1999-2005	1971-2005
Direct loss in IEI-acres	29,760	37,065	31,115	119,459
Indirect loss in IEI-acres	115,197	132,855	129,477	356,005
Overall loss in IEI-acres	144,957	169,920	160,592	475,464
Ratio of indirect loss to direct loss	**3.9**	**3.6**	**4.2**	**3.0**

Furthermore, examination of individual towns between 1971 and 2005 shows that in a few towns the indirect impacts can be as much as 8 times greater than the direct impacts. The towns that see the greatest indirect impacts to development are precisely the towns that have the largest intact blocks of habitat remaining in the state.

Figure 3.7: Effects of development—beyond the footprint (1971-2005)



In all past editions of *Losing Ground*, Mass Audubon has used the best available data to estimate the acres of *direct* impact due to development. The CAPS analysis shows that the *indirect* impacts of development have an even larger negative impact on the ecological integrity of our natural lands. Faced with these conclusions, the challenge to conservation agencies and organizations is twofold: 1) to protect as much of the high-quality habitat that remains at local, regional, and statewide scales; and 2) to find ways to change the pattern of dispersed residential development that is so prevalent. The CAPS analysis clearly shows that it is exactly this type of development that will most quickly degrade the ecological integrity of the landscape.

CHAPTER 4: THE STATE OF LAND PROTECTION IN MASSACHUSETTS—FORESTS, WETLANDS, AND AGRICULTURE

Massachusetts' land area is currently more than one-fifth (20.6%) permanently protected wildlife habitat. This is up from 18.8 percent in 2003 and 17.3 percent in 1997. We have protected one million acres of wildlife habitat: 404,000 acres for conservation only; 418,500 acres for conservation and recreation; and 206,900 acres for water supply protection.

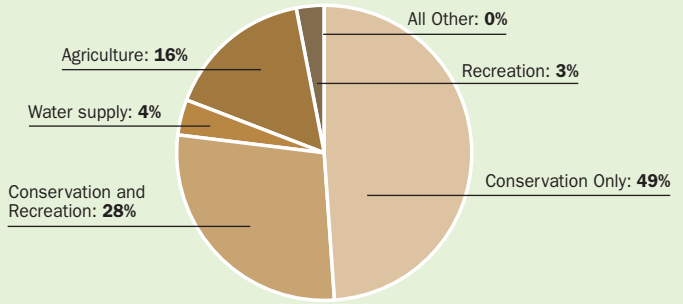
The best source of information on the state of land protection in Massachusetts continues to be the Protected Recreation and Open Space data available from MassGIS. This is a Geographic Information Systems (GIS) database, allowing both spatial and statistical analysis of protection levels.

Table 4.1: Type of ownership and primary purpose of protection, December 2008

	State	Municipal/ County	Nonprofit org	Private w/ restriction	Federal	Other	Total
All Polygons from Open Space Layer	570,141	351,009	133,162	227,216	65,872	12,316	**1,359,716**
Permanently Protected Land only	559,017	272,423	112,342	148,808	61,938	8,497	**1,163,025**
Conservation only	130,511	112,662	84,243	63,608	12,739	252	**404,015**
Conservation and Recreation	317,716	29,218	20,542	14,462	36,490	80	**418,508**
Water Supply Protection	98,452	95,778	44	3,565	2,931	6,176	**206,946**
Agriculture	860	1,156	3,128	62,376	–	1,858	**69,378**
Recreation only	6,732	26,704	1,464	2,018	794	50	**37,762**
Historical/Cultural/ Scenic	38	5,052	2,240	1,820	1,636	79	**10,865**
Other	4,707	1,854	681	958	7,347	1	**15,548**

Table 4.1 presents this acreage by type of ownership and primary purpose of protection. Since the last edition of *Losing Ground*, the land categorized as having a "conservation only" purpose has increased from 33% to 35% of all permanently protected lands. This is a significant increase given such a large protected land area. The shift can be explained by the greater amounts of land being protected with the sole purpose of conservation. Between 1999 and 2005, 49% of land protected was for the sole purpose of conservation.

Figure 4.1: Primary purpose of protection between 1999 and 2005



Who Owns Our Protected Lands?

Table 4.2 shows how the purpose of protection varies based on the type of ownership. Overall, nearly 50% of permanently protected land is state owned. Almost all state-owned land is managed by the Department of Fish & Game and the Department of Conservation and Recreation. Municipal land is protected primarily for conservation or for water supply protection. Within the nonprofit category, 75% of the land is protected for conservation purposes. Private land that is permanently protected is dominated and equally split between conservation and agricultural purposes. The relatively small amount of Federal land has a breakdown very similar to state land.

Table 4.2: Percentage breakdown of primary purpose by ownership type

	State	Municipal/ County	Nonprofit org	Private w/ restriction	Federal	Other	Total
Permanently protected land only	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	**100.0%**
Conservation only	23.3%	41.4%	75.0%	42.7%	20.6%	3.0%	**34.7%**
Conservation and Recreation	56.8%	10.7%	18.3%	9.7%	58.9%	0.9%	**36.1%**
Water Supply Protection	17.6%	35.2%	0.0%	2.4%	4.7%	72.7%	**17.8%**
Agriculture	0.2%	0.4%	2.8%	41.9%	0.0%	21.9%	**6.0%**
Recreation only	1.2%	9.8%	1.3%	1.4%	1.3%	0.6%	**3.2%**
Historical/Cultural/ Scenic	0.0%	1.9%	2.0%	1.2%	2.6%	0.9%	**0.9%**
Other	0.8%	0.7%	0.6%	0.6%	11.9%	0.0%	**1.3%**

The Good News

Between 1999 and 2005, the open space database reported 109,863 acres of land that was permanently protected (Table 4.3) This represents a protection rate of 43 acres per day. Between 1999 and 2005, the rate of land protection was double the rate of development in Massachusetts. However, only 50% of this protection had the sole purpose of conservation. The rate of land protection was highest in 2000, 2001, and 2002, with more than 20,000 acres being protected in each of those years. The rate of land protection between 2003 and 2005 was much less.

The Executive Office of Energy and Environmental Affairs (EEA) recently announced that 24,100 acres were protected in Fiscal Year 2008 through EEA action, almost double that protected in FY2007. Roughly 13,800 acres were protected via expenditure and 10,300 acres through conservation restrictions. This is exciting news and, with the help of the Environmental Bond, it is likely the first of several years with high levels of land protection.

Table 4.3: Acres protected between 1999 and 2005 by primary purpose

Primary Purpose of Conservation	1999	2000	2001	2002	2003	2004	2005	Total
Conservation only	6,434	11,865	13,483	12,470	3,139	2,236	4,500	**54,127**
Conservation and Recreation	2,343	5,110	4,851	9,385	3,286	4,302	1,537	**30,814**
Water Supply	821	172	1,529	1,362	14	433	119	**4,450**
Agriculture	2,313	3,613	3,272	2,185	1,531	2,384	1,746	**17,044**
Recreation	6	127	17	2,767	99	–	303	**3,319**
All Other	–	5	1	2	45	39	17	**109**
TOTAL (All permanently protected lands)	**11,917**	**20,892**	**23,153**	**28,171**	**8,114**	**9,394**	**8,222**	**109,863**

The Bad News

Two other statewide conservation plans used as benchmarks show that although we have made significant progress in land protection, there is still much work to do. The Statewide Conservation Plan, endorsed in 2003 by then EOEA Secretary Herzfelder and summarized in the last edition of *Losing Ground*, called for 50,000 acres of protection each year in order to meet its goals. The year with the highest rate of protection, 2002, fell more than 20,000 acres short of this goal, and since then protection rates have fallen. Unfortunately, this plan was not implemented in any substantive manner during the Romney Administration. The Wildlands and Woodlands vision of the Harvard Forest calls for protection of half of the state, or 2.5 million acres. At the 1999-2005 rate of land protection, it would take roughly 85 years to reach the 2.5-million-acre goal. Given the indirect impacts of development described in Chapter 3, this rate of protection will not be adequate to fulfill the vision of wildland reserves with surrounding managed woodlands.

IMPROVEMENTS TO THE MASSGIS PROTECTED LAND DATABASE

MassGIS Protected Recreation and Open Space data is one of the most useful sources of information on land protection in Massachusetts. In recent months, MassGIS has taken steps that will lead to many improvements. The result will be a more up-to-date data set on the protection of open space in the Commonwealth.

A past hurdle of this dataset was the inability of individuals and organizations to provide spatial data to MassGIS without purchase and knowledge of GIS software. MassGIS is currently developing an online "Open Space Wiki" where local officials and land trusts can submit parcel data into the open space data set electronically.

Another improvement that will yield more up-to-date information is the submission of map (spatial) information to MassGIS for all conservation restrictions and all Executive Office of Energy and Environmental Affairs grant programs.

A final important improvement is that the rate of entry of state data into the database has greatly improved. We should expect to see state acquisitions of parcels in any fiscal year be reflected in the database within several months of June 30th. If the data in the open space data set is current, conservation agencies and organizations can ask the basic question, "What have we protected in the past year?" Previously, we have not been able to reliably answer this important question.

Some challenges remain when it comes to open space data. Parcels privately held by small nonprofit organizations may still not be reflected in the open space data set for a variety of reasons. While the Massachusetts Conservation Mapping Assistance Partnership Program of MassGIS provides inexpensive GIS software, training, and data viewers to land trusts and conservation commissions, it has not yet reached everyone it could.

Protection of Natural Lands

Massachusetts currently has 3.5 million acres of land in a natural state. Overall, 28.4% of the natural landscape is protected. Table 4.4 shows the breakdown of each natural land use type. According to the 2005 Land Use/Land Cover data, approximately 3,187,100 acres (91%) is forested. Much of the brushland/successional habitat that is protected is on Martha's Vineyard where 82% of its 4,270 acres is protected and on Nantucket where 55% of its 11,680 acres is protected. On the mainland, 28% of the remaining 15,720 acres is protected. This habitat will often be host to a unique suite of early successional species and represents potential land that can be actively managed to promote these species. While powerlines are built by humans and continue to be managed, they are also host to species found only in early successional habitats. For this reason, they were included as a natural land use type.

BETWEEN 1999 AND 2005, THE RATE OF LAND PROTECTION WAS DOUBLE THE RATE OF DEVELOPMENT.

Table 4.4: Breakdown of natural land in Massachusetts (2005)

Land Use	Acres in Forested/Natural	Acres Protected	Percent Protected
Forested	2,899,417	813,565	28.1%
Nonforested wetland	165,625	50,543	30.5%
Salt wetland	43,711	18,999	43.5%
Powerlines	27,911	5,268	18.9%
Saltwater sandy beach	50,774	14,204	28.0%
Forested wetland	287,701	78,138	27.2%
Brushland/successional	31,676	14,276	45.1%
TOTAL	**3,506,815**	**994,993**	**28.4%**

To identify the natural portions of the state that are under the highest threat from development, we used the town-specific rates of development between 1999 and 2005 (acres of development per square mile) as an indicator of threat to the remaining habitat. We then calculated the acres of unprotected natural land that remains in each town. Since the distribution of natural land varies widely by municipality, we grouped the towns into four categories based on acres of unprotected forest/natural, > 10,000 acres, 5,000-10,000 acres, 1,000-5,000 acres, and < 1,000 acres. As the acreage of natural land in towns decreases, the amount of protection generally increases from 25% to just under 60% in the category with the smallest amounts of natural land.

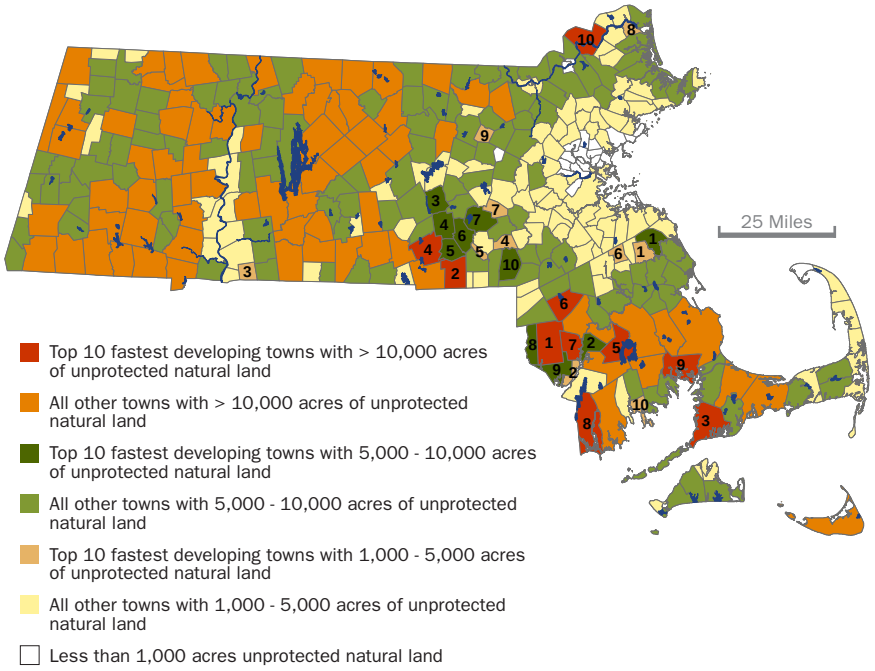
Table 4.5: Amount and Protection of natural land in Massachusetts

Unprotected natural category	Number of towns	Land in natural	Percent protected
> 10,000 acres	83	1,568,981	25.1%
5,000-10,000 acres	136	1,388,344	30.3%
1,000-5,000 acres	109	509,279	33.0%
< 1,000 acres	23	19,788	59.5%

We identified the top 10 communities in each category that are most under threat of development. Seven of the top 10 threatened towns with more than 10,000 acres of natural land are clustered in southeastern Massachusetts, with the remaining towns in the Blackstone River watershed and in Haverhill (Figure 4.2). Rehoboth, for instance, has more than 20,000 acres of natural lands that remain unprotected, and 12 acres of every square

mile have been developed since 1999. The towns shown in dark green identify a cluster of towns to the east and southeast of Worcester that have between 5,000 and 10,000 acres of unprotected natural land and high rates of development. This analysis reinforces the conclusion from the previous edition of *Losing Ground* that sprawl continues to impact towns in southeastern Massachusetts. Detailed examination of the towns with the highest rates of development shows that the sprawl has moved to even farther flung portions of southeastern Massachusetts. In addition, it highlights the Blackstone River watershed as a hot spot where development is having, and will continue to have, a significant impact on the remaining natural resources.

Figure 4.2: Natural lands and development in Massachusetts



Protection of Agricultural Lands

According to the 2005 Land Use/Land Cover data, Massachusetts has roughly 285,800 acres of agricultural land, or 5.5% of the state. Table 4.6 shows how this acreage is distributed in various types of agriculture.

Table 4.6: Breakdown of agricultural land in Massachusetts (2005)

Land use	Acres in agriculture	Acres protected	Percent protected
Cropland	159,011	33,119	20.8%
Pasture	87,899	12,808	14.6%
Cranberry bogs	24,203	1,551	6.4%
Orchard	8,759	2,803	32.0%
Nursery	5,948	891	15.0%
TOTAL	**285,820**	**51,172**	**17.9%**

The majority of agriculture is in cropland (56%), with pasture (31%) and cranberry bogs (8%) also making significant contributions to the agricultural land base. Roughly 21% of the state's cropland is protected, as is 15% of the state's pasture. The cranberry bogs, primarily located in southeastern Massachusetts, suffer from a low level of protection (6%). However, these bogs represent wetlands that were converted to cranberry production long ago, and as such are not readily developable. A thorough investigation of threats to commercial cranberry bogs would take into account the quality of protection afforded adjacent upland areas as well as the bogs themselves. This type of analysis should be completed for this important cultural and agricultural resource.

To identify the agricultural portions of the state that are under the highest threat from development, we used the town-specific rates of development between 1999 and 2005 (acres of development per square mile) as an indicator of the threat to remaining habitat. We then calculated the acres of unprotected agricultural land that remain in each town. The distribution of agricultural land varies widely by town, so we grouped the towns into four categories based on acres of unprotected agriculture: > 2,500 acres, 1,000-2,500 acres, 250-1,000 acres, and < 250 acres.

Table 4.7: Amount and protection of agricultural land in Massachusetts

Unprotected agriculture category	Number of towns	Land in agriculture	Percent protected
> 2,500 acres	12	49,922	14.5%
1,000-2,500 acres	68	125,799	17.6%
250-1,000 acres	136	94,123	19.0%
100-250 acres	54	12,529	22.0%
< 100 acres	81	3,447	32.9%

Towns with small amounts of agriculture remaining (< 100 acres) provide much higher levels of protection to this scarce resource, almost 33%. In contrast, those towns with large acreages that remain in agriculture protect less than 15% of the agricultural land.

We identified the top 10 towns in each category that are most under threat of development. The pattern of threatened towns that emerges is interesting. If we focus on towns with large amounts of agricultural land remaining (> 2,500 acres shown in red on Figure 4.3), six out of the ten most threatened towns are in the southeast, arguing for increased protection of agricultural lands in this region. The remaining most threatened towns are clustered in the Connecticut River valley and in the river valleys in the northwest and southwest of the state. This pattern is significant because it shows that in order to protect the state's agricultural land, we must focus on growth in the Connecticut River valley as well as in the far western corners of the state. The nature of the protection must also vary. In southeastern Massachusetts, the uplands surrounding cranberry bogs must be protected while in other parts of the state outright protection of the upland agricultural land is more appropriate.

Figure 4.3: Agriculture and development in Massachusetts