Conservation Assessment and Prioritization System (CAPS) Statewide Massachusetts Assessment: November 2011

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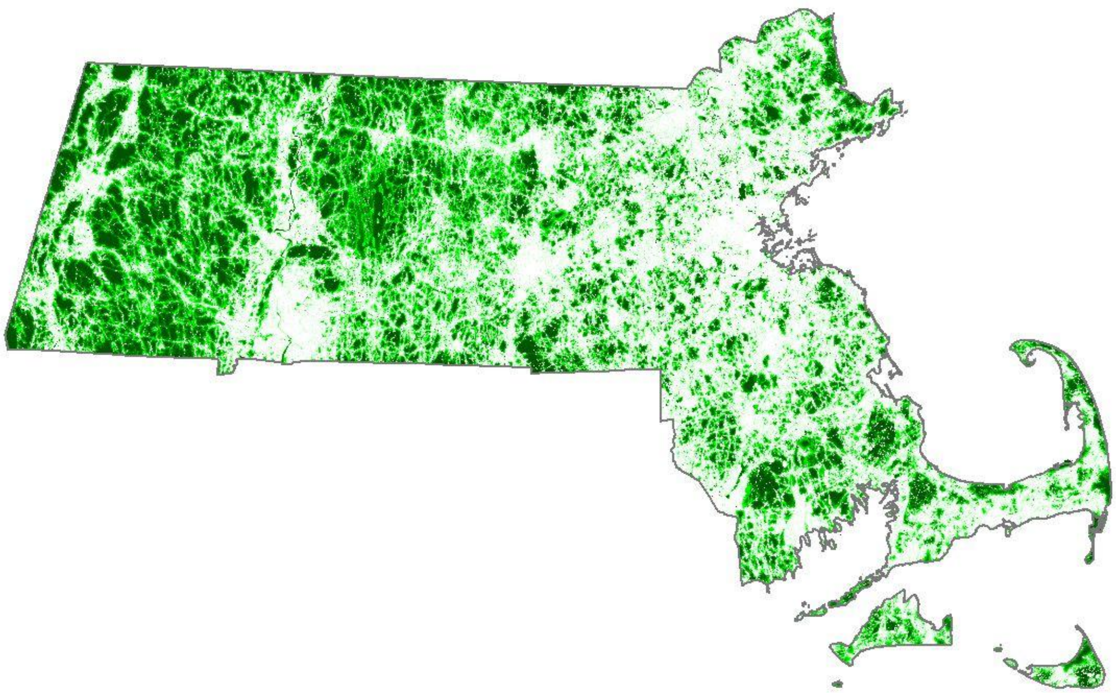

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Introduction

The Conservation Assessment and Prioritization System (CAPS) is an ecosystem-based (coarse-filter) approach for assessing the ecological integrity of lands and waters and subsequently identifying and prioritizing land for habitat and biodiversity conservation. We define ecological integrity as the ability of an area to support biodiversity and the ecosystem processes necessary to sustain biodiversity over the long term. CAPS is a computer software program and an approach to prioritizing land for conservation based on the assessment of ecological integrity for various ecological communities (e.g., forest, shrub swamp, headwater stream) across the landscape.

In November 2011 the Landscape Ecology Program at the University of Massachusetts Amherst completed its first comprehensive, statewide assessment of ecological integrity using CAPS. The results from this assessment are available from our web site: www.masscaps.org. The results are available in four formats.

- Georeferenced TIFF files (GeoTIFFs) for download and use with image viewers, web browsers or GIS software
- Arc grids available for download and use with GIS software
- Maps for each city and town in Massachusetts depicting Integrated Index of Ecological Integrity (IEI) scores
- Maps depicting “Habitat of Potential Regional and Statewide Importance” as defined in MassDEP’s “Massachusetts Wildlife Habitat Protection Guidance for Inland Wetlands”

A companion document, CAPS Technical Guide (to be available in the near future), will discuss CAPS in considerably more detail, including the conceptual underpinning, model verification, and more detailed descriptions of individual metrics.

Overview of CAPS

The first step in the CAPS approach is the characterization of both the developed and undeveloped elements of the landscape. Developed land uses are grouped into categories such as various classes of roads and highways, high-intensity urban, low-density residential, agricultural land, and other elements of the human dominated landscape. Undeveloped (“natural”) land is mapped based on ecological community classification (e.g., forest, coastal beach, shrub swamp, salt marsh, bog, pond).

With a base map depicting various classes of developed and undeveloped land, we then evaluate a variety of landscape-based variables ("metrics") for every point in the landscape. A metric may, for example, take into account the microclimatic alterations associated with "edge effects," intensity of road traffic in the vicinity, nutrient loading in aquatic ecosystems, or the effects of human development on landscape connectivity.

Integrity metrics - Beginning with a digital base map depicting various classes of developed and undeveloped land and a number of auxiliary layers representing anthropogenic alterations (such as road traffic and imperviousness) and ecological variables (such as wetness and stream gradient), we computed a variety of landscape metrics to evaluate ecological integrity for every point in the landscape. A metric may, for example, take into account how well a point in the landscape is connected to similar points, the intensity of traffic on nearby roads, or the expected vulnerability to invasions by exotic plants. Appendix C lists the landscape metrics used in CAPS.

Various metrics are applied to the landscape and then integrated in weighted linear combinations as models for predicting ecological integrity. This process results in a final Index of Ecological Integrity (IEI) for each point in the landscape based on models constructed separately for each ecological community. Intermediate results are saved to facilitate analysis—thus one can examine not only a map of the final indices of ecological integrity, but maps of road traffic intensity, connectedness, microclimate alterations, and so on. Note that metrics do not apply to developed land—all cells corresponding to developed land cover types are given an index of ecological integrity (IEI) score of zero, even though we recognize that some developed land may contribute to the conservation of biodiversity.

Combining Metric Results – Results from the landscape metrics are rescaled, weighted, and then combined into an overall index of ecological integrity. First, the results of each metric are rescaled by percentiles for each community so that, for instance, the best 10% of marshes have values ≥ 0.90, and the best 25% have values ≥ 0.75. This is done to adjust for differences in units of measurement among metrics and to account for differences in the range of metric values for each community. The rescaling by community is done to facilitate identification of the "best" of each community, as opposed to the best overall – which is strongly biased towards the dominant, matrix-forming communities (i.e., forest).

Next, the rescaled values are weighted (weights are assigned by expert teams), to reflect the relative importance of each metric for each community (Appendix F), and then added together to compute an overall index of ecological integrity. Thus, the final index of ecological integrity for each cell is a weighted combination of the metric outputs for that cell, based on the community within which the cell falls.

Identifying and Prioritizing Land for Conservation Action – Among its many uses, the index of ecological integrity can be used alone or in combination with other approaches to identify and prioritize land for conservation. The index can be used, for example, to identify the top 10% or 30% of the land likely to provide the greatest ecological value over time and providing an effective and credible basis for strategic land conservation. It is important to note that the ecological integrity scores for land depend on the geographic extent of the analysis area. This is because the rescaling of the metrics is done to identify the best of the available lands, yet the "available lands" varies with geographic location and extent. Thus, the best example of a particular community within a certain geographic extent might be a relatively poor example when assessed over a much larger extent. For this reason, CAPS can rescale the index of ecological integrity to reflect conditions within geographic units that make up the full area of analysis. The November 2011 CAPS assessment provides results at three geographic scales: statewide, major watersheds, and ecoregions.

Project Area

This analysis was done for the entire Commonwealth of Massachusetts. Estuarine waters and salt ponds were included, but open ocean is not treated as a community by CAPS. Data limitations at state boundaries affect values near the borders with other states, though all of our metrics correct for edges (with the assumption that conditions beyond data edges are similar to those in the vicinity). Flow volume and stream sizes for rivers flowing into Massachusetts are accounted for, using flow accumulation data from the National Hydrography Dataset. Although the Spring 2009 CAPS run included all of Massachusetts, this is the first version to fully assess coastal community types using the coastal metrics.

Methods

Input Data

GIS data from a variety of sources were combined to create a base map depicting natural communities, developed land types, and roads. Appendix B describes the GIS data used. All data are mapped in 30 m grids. The final land cover layer depicts natural communities, development and roads. See Appendix E for a description of natural communities, and Appendix H for the land cover classification. Other data layers depict subsets of this final land cover, including roads, railroads, and streams layers. A set of 23 Ecological Settings variables (Appendix D) describe abiotic, vegetational, and anthropogenic attributes of each cell. Finally, a number of ancillary layers are used by specific metrics. These include elevation, flow direction, flow resistance, and traffic rates.

CAPS Analysis

The full details of the CAPS analysis conducted for this project are beyond the scope of this report (see the forthcoming CAPS Technical Manual). Briefly, once the input data layers are created, analysis in CAPS requires a model to be defined for each natural community or broad ecological system. Each community's model entails selecting a number of metrics and weighting them by importance for that community. This model parameterization was originally done by three expert teams as part of the Housatonic watershed pilot project. An expert team for coastal communities met in 2010. Additional parameterization and some necessary modifications were done for this project by Kevin McGarigal, Scott Jackson, and Brad Compton. Andy Finton, Alison Bowden, and Jessica Dyson from The Nature Conservancy (TNC) provided valuable insights into parameters. The metrics selected for each of the communities and their relative weights are listed in Appendix F.

The parameterized model is run on the input layers using the CAPS software, written at UMass by Brad Compton and Eduard Ene. This software produces an output grid for each metric. Metrics fall into two groups: stressor metrics (such as road traffic, invasive plants, or nutrient enrichment), and resiliency metrics (similarity, connectedness, and aquatic connectedness). Stressor metrics measure anthropogenic stressors that reduce the integrity of a site, while resiliency metrics measure the intrinsic ability of a site to maintain its ecological integrity, despite the impact of anthropogenic stressors. Resiliency metrics, in reflecting the current landscape, do take into account anthropogenic stressors such as road traffic and impervious surfaces. The three resiliency metrics are based on the ecological distance among cells computed using the ecological settings variables described in Appendix D.

These output grids are rescaled, weighted, and combined into final index of ecological integrity (IEI) values. The IEI for each cell is a weighted combination of the metric outputs for that cell, based on the community in which the cell falls. Results are rescaled by percentiles, so that, for instance, the best 10% of marshes have values ≥ 0.90, and the best 25% have values ≥ 0.75. A separate analysis allows each cell to be assessed in the context of its watershed or ecoregion. For these analyses, the IEI is rescaled by percentiles within each watershed or ecoregion. For example, if the IEI is rescaled by watershed, a marsh with a value of 0.85 would be interpreted as being in the 85th percentile of marshes for its watershed. When rescaling by the full extent (statewide), the high-valued forests are primarily in western Massachusetts; rescaling by ecoregion or watershed spreads high IEIs more equitably across the state.

We rescaled results at three extents (full extent, rescaled by major watershed, and rescaled by ecoregion), plus a final integrated rescaling. The integrated rescaling uses the maximum score from statewide and watershed analyses for each cell in wetland and aquatic communities, and the maximum score from statewide and ecoregion analyses for cells in upland communities. The resulting IEI is then rescaled again by community to preserve the interpretation (i.e., the top 10% of IEI values represent 10% of the landscape). See Table 1 for a summary of the various IEIs.

Table 1. Summary of different scalings of the Index of Ecological Integrity.

Grid name	Extent	Explanation
IEI	statewide	Each community is scaled across the full extent (statewide)
IEI-E	by ecoregion	Each community is scaled separately within each ecoregion
IEI-W	by watershed	Each community is scaled separately within each major watershed
IEI-I	integrated	IEI result for each community are integrated using combinations of statewide, watershed and ecoregion results

CAPS treats the results for each community separately, thus IEI should be compared only within communities. IEI is a relative measure, thus a powerline shrubland may have a high IEI, meaning that it has high integrity compared to other powerlines—this does not imply that it is pristine, or that it has more integrity than a medium-IEI wetland.

Data Accuracy and Limitations

The GIS data used in CAPS comes from a variety of sources, and the quality of these data are variable. We integrated these data sources into a single land cover map, with several parallel data layers, including settings variables and other ancillary layers. We put considerable effort into integrating these input layers in ways that maximized the accuracy of available data, while making sure the final map generally makes sense, both visually and for use in the CAPS metrics. Because input data came from several different sources, we have no estimate of the accuracy of the final data set, nor of the effect errors in the base map may have had on final CAPS results.

Nobody should have any illusions that the base map presents a “true” depiction of the landscape—a comparison of the landcover with aerial photos or with familiar places will turn up errors in classification and position. Furthermore, the classification is fairly coarse, and distinctions between classes such as marsh and shrub swamp are necessarily arbitrary. Many of these communities change over time, so our snapshot based on data generated over several years may depict today’s beaver pond as yesterday’s forested wetland. The primary known issues with specific input layers are discussed in Appendix B.

We believe that the effects of many of the data errors will be relatively small. CAPS operates at fairly broad scales, looking at the effects of the surrounding landscape on any particular point. Small errors in classification and placement (small roads and streams omitted, marshes slightly shifted, small forest patches lost because of the grain of the map) will usually have a small but negligible effect on final results. In the future we plan to evaluate the effects of various kinds of errors on CAPS results.

The coarseness of the classification scheme is perhaps a larger issue. Available data necessitated lumping many different forest communities into a single class; likewise, many rare and small-patch-forming communities are omitted. This leaves CAPS unable to compare patches of rich mesic forest to other patches of rich mesic forests, or to evaluate acidic rocky outcrops. To the extent possible given data limitations, the settings variables (Appendix D) are meant to distinguish among communities at a fine scale; these settings variables are used in the similarity, connectedness, and aquatic connectedness metrics.

CAPS is a comprehensive assessment (models are applied uniformly to all areas) and relies on data that are broadly available across Massachusetts. The Index of Ecological Integrity is meant to give a general estimate of the integrity of a site, but we recommend using it in conjunction with other data in order to get a fuller picture of ecological status of areas within Massachusetts, including:

- Sources of degradation that may be mapped but are difficult to model (e.g., toxic pollution)
- Sources of degradation that are not comprehensively mapped (e.g., past land use)
- Data that might suggested increased conservation value but that are not comprehensively mapped (e.g., certified vernal pools, rare species records)
- Data that might suggest higher conservation value even though it is not related to ecological integrity (e.g., protected status, inclusion within an ACEC)

Results

CAPS data and results can be downloaded from our web site: www.masscaps.org (see Appendix I). CAPS results are available in four formats.

- Georeferenced TIFF files (GeoTIFFs). GeoTIFF file sizes are generally smaller than Arc grids. They can be viewed using an image viewer, web browser, or with GIS software. GeoTIFFS are available for IEI, land cover, metrics (raw and scaled) and ecological settings variables. IEI and scaled metric values in GeoTIFFs are scaled from 0 (low) to 100 (high).

- Arc grids for use with GIS software. Arc grids are also available for land cover, metrics (raw and scaled) and ecological settings variables. IEI and scaled metric values are scaled from 0 (low) to 1 (high).

- Maps for each city and town in Massachusetts depicting the Integrated Index of Ecological Integrity (IEI-I) scores. These maps are in the form of high-resolution PDFs depicting areas in the top 50% of values using integrated IEI scores. Ecological communities are differentiated by color for the following categories: forest (green), shrubland (orange), coastal uplands (yellow to brown), coastal wetlands (cyan) and freshwater wetlands and aquatic (blue). For all ecological community types darker colors indicating higher-valued cells.

- Maps depicting "Habitat of Potential Regional and Statewide Importance" as defined in MassDEP's Massachusetts Wildlife Habitat Protection Guidance for Inland Wetlands. These maps, also known as "Important Habitat" maps, are available as high-resolution PDFs for each town and city. They are based on the integrated index of ecological integrity and depict all areas (not just regulated "resource areas") that score in the top 40% for IEI-I. Areas so designated as "Habitat of Potential Regional and Statewide Importance" represent 40% of the undeveloped landscape as well as 40% of each ecological community (e.g. forest, shallow marsh, shrub swamp, forested wetland, salt marsh). "Important Habitat" data are also available for download as Arc grids or GeoTIFFs.

CAPS results are best explored interactively, using a GIS that can display grids (e.g., ArcView, ArcMap or QGIS). See Appendix I for information on downloading data. The most generally useful results are the landcover and IEI grids.

The landcover grid (Fig. 1) represents developed land and broad natural communities. Landcover classes and names are listed in Appendix H, and ArcView, ArcMap and QGIS legends are provided with the data. The TIFF version of landcover is already colored appropriately, so no separate legend file is required.

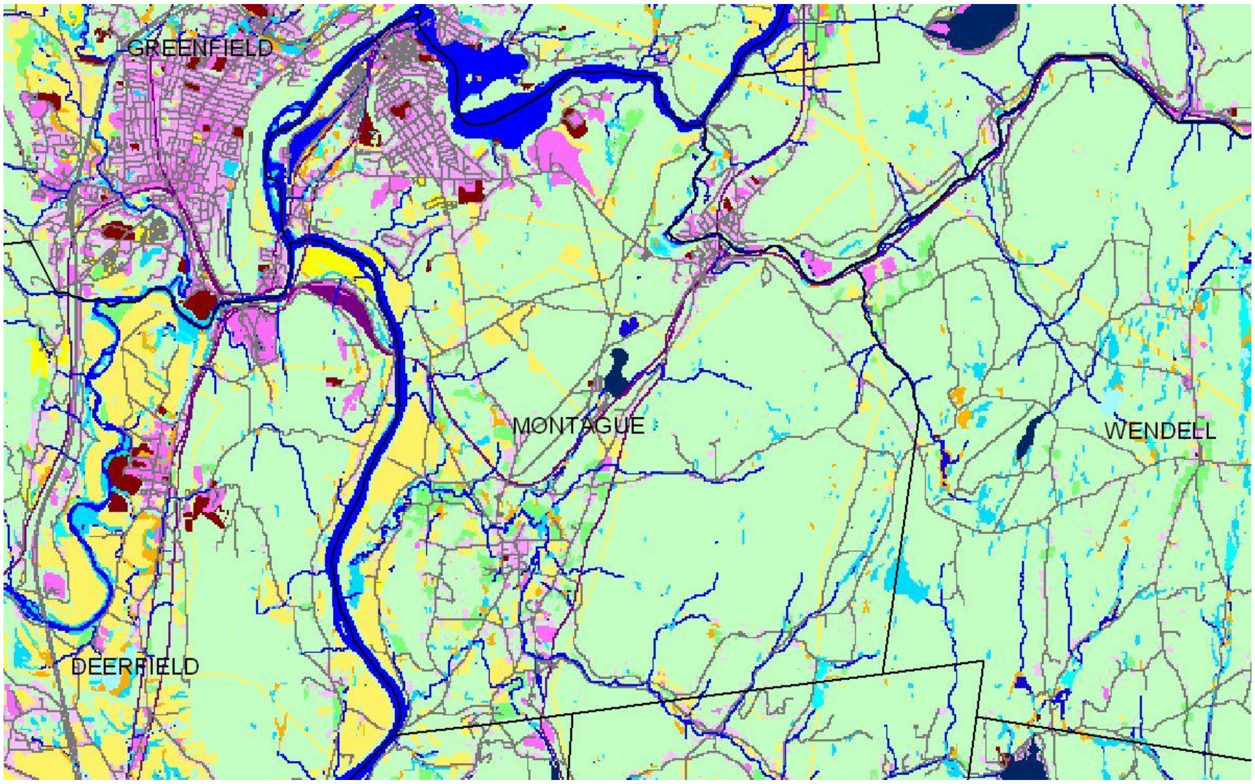

Fig. 1. Landcover for the town of Montague.

The IEI grids present the Index of Ecological Integrity at four scales: the entire project area (statewide), watershed, ecoregion, and integrated. Figures 2 through 5 show statewide IEI (Fig. 2), IEI scores rescaled by watershed (Fig. 3) and by ecoregion (Fig. 4), and integrated IEI (Fig. 5), with darker colors indicating higher-valued cells. Note that in Figure 2 most of the high-value falls in forests in the western half of the state. In Figures 3, 4 and 5 the ecoregional and watershed scaling has reallocated the high IEIs across the state.

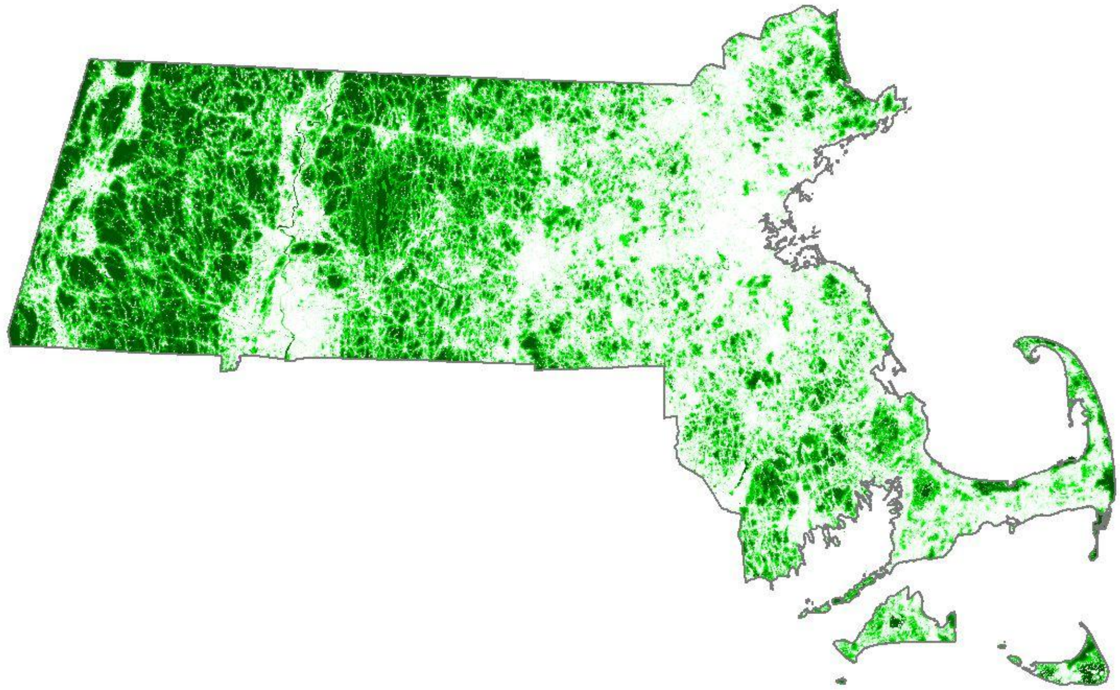

Fig. 2. Statewide IEI (IEI).

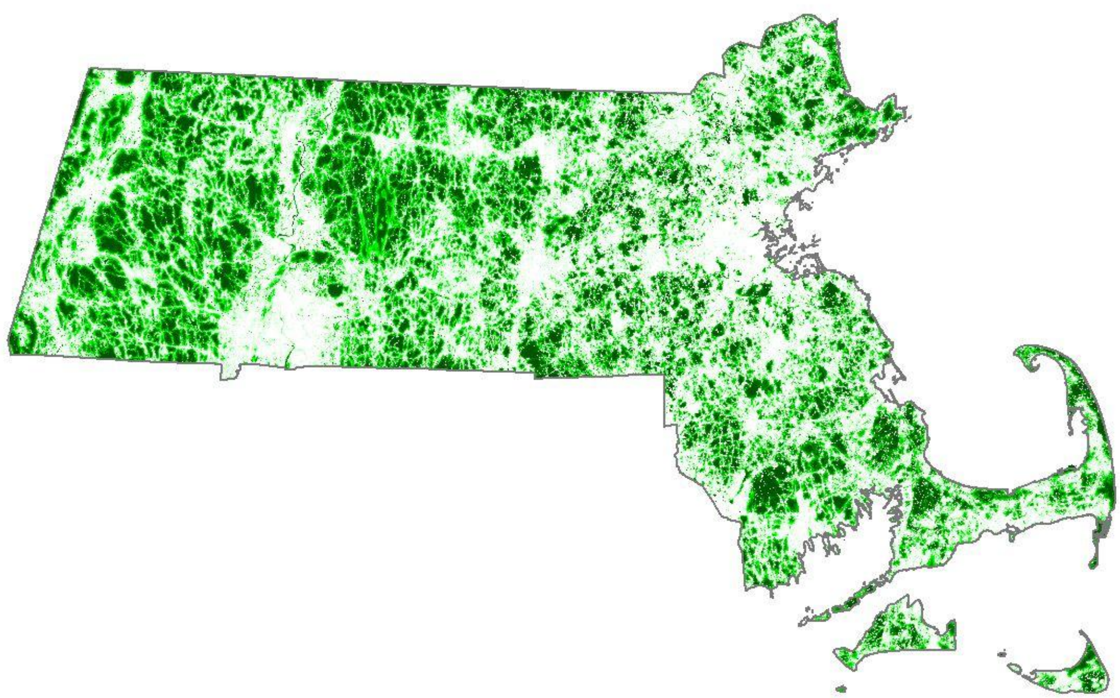

Fig. 3. IEI rescaled by Major Watershed (IEI-W).

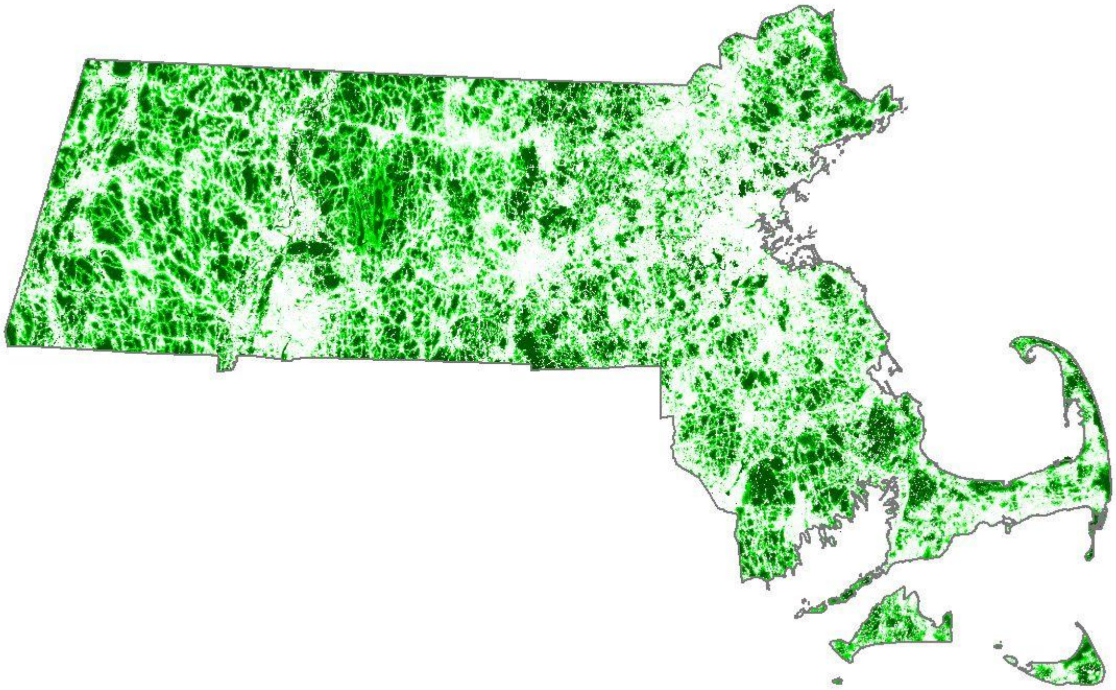

Fig. 4. IEI rescaled by Ecoregion (IEI-E).

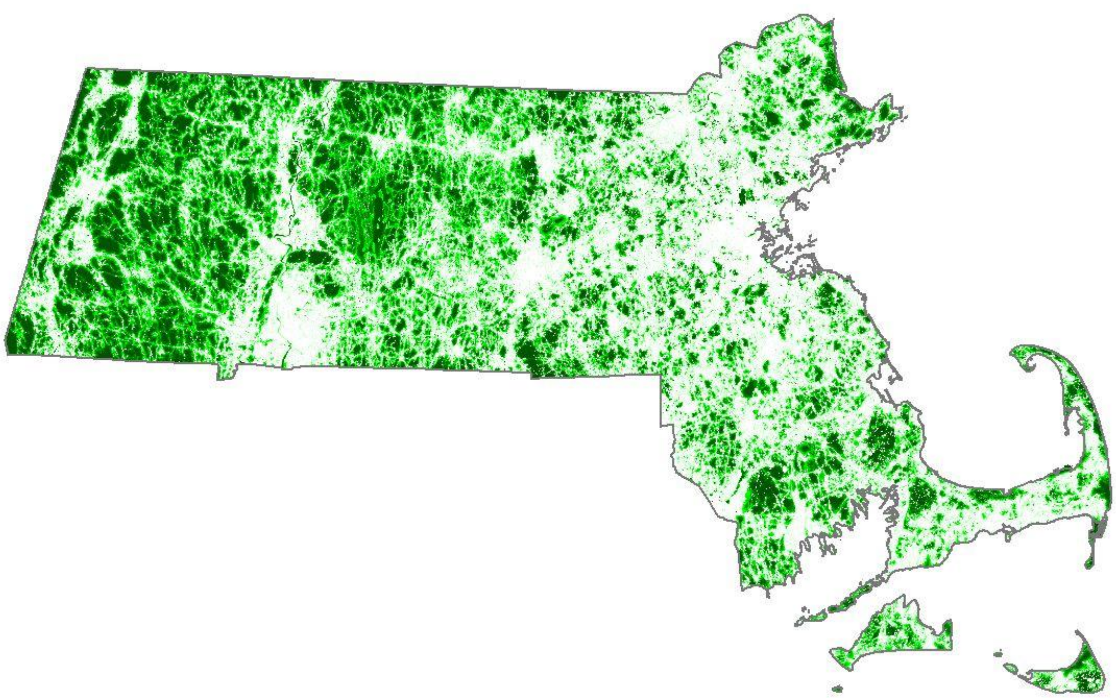

Fig. 5. Integrated IEI, a combination of statewide, watershed and ecoregionally scaled results (IEI-I).

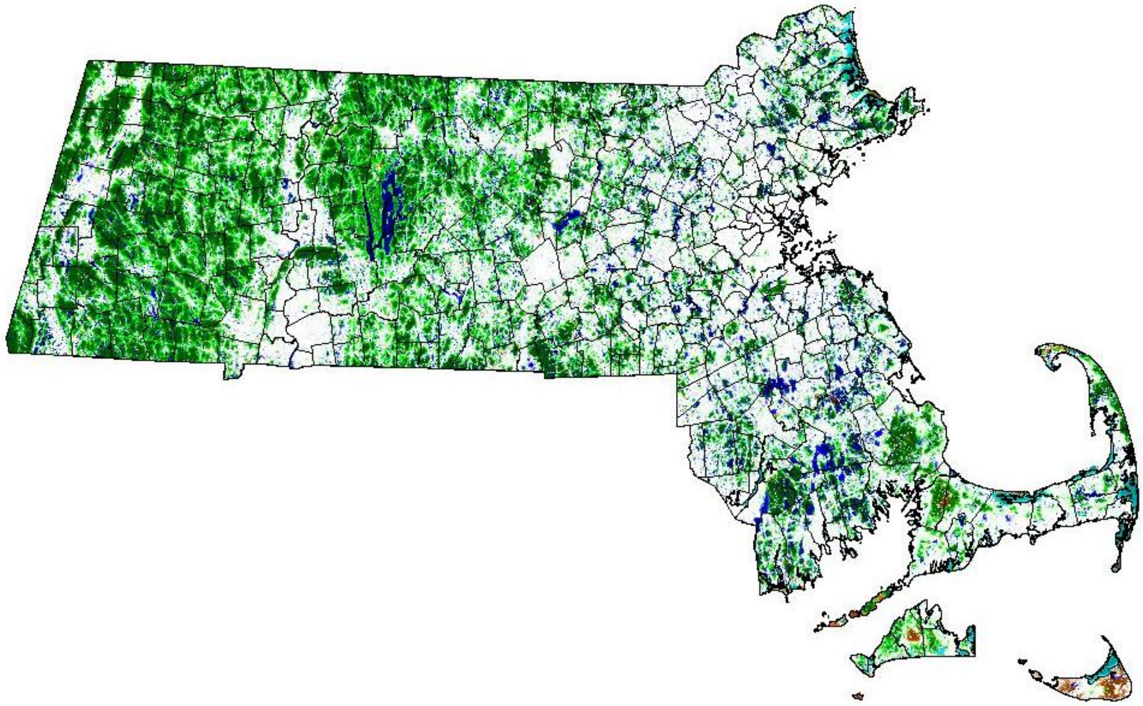

Fig. 6. Integrated IEI (IEI-I) depicted using a five-color scheme: forest (green), shrubland (orange), coastal upland (yellow to brown), freshwater wetlands and aquatic (blue) and coastal wetlands (cyan). For all community types darker color represents higher IEI-I scores.

Figure 6 depicts the integrated IEI using a five-color scheme that makes it easier to differentiate among various groups of ecological communities. Because IEIs are scaled from 0 to 1 by percentiles within each community, images such as Figures 2 through 5 tend to be visually dominated by the values for forest communities because the landscape of Massachusetts is mostly forest. The five colors represent five broad groups of ecological communities: forest, shrubland, freshwater wetland and aquatic, coastal wetland and coastal upland. By using different colors to represent these five broad community types it is easier to recognize high-quality stream segments and patches of shrubland, wetlands and coastal communities that might otherwise go unnoticed among the large patches of forest throughout much of the state (Fig. 7 and 12).

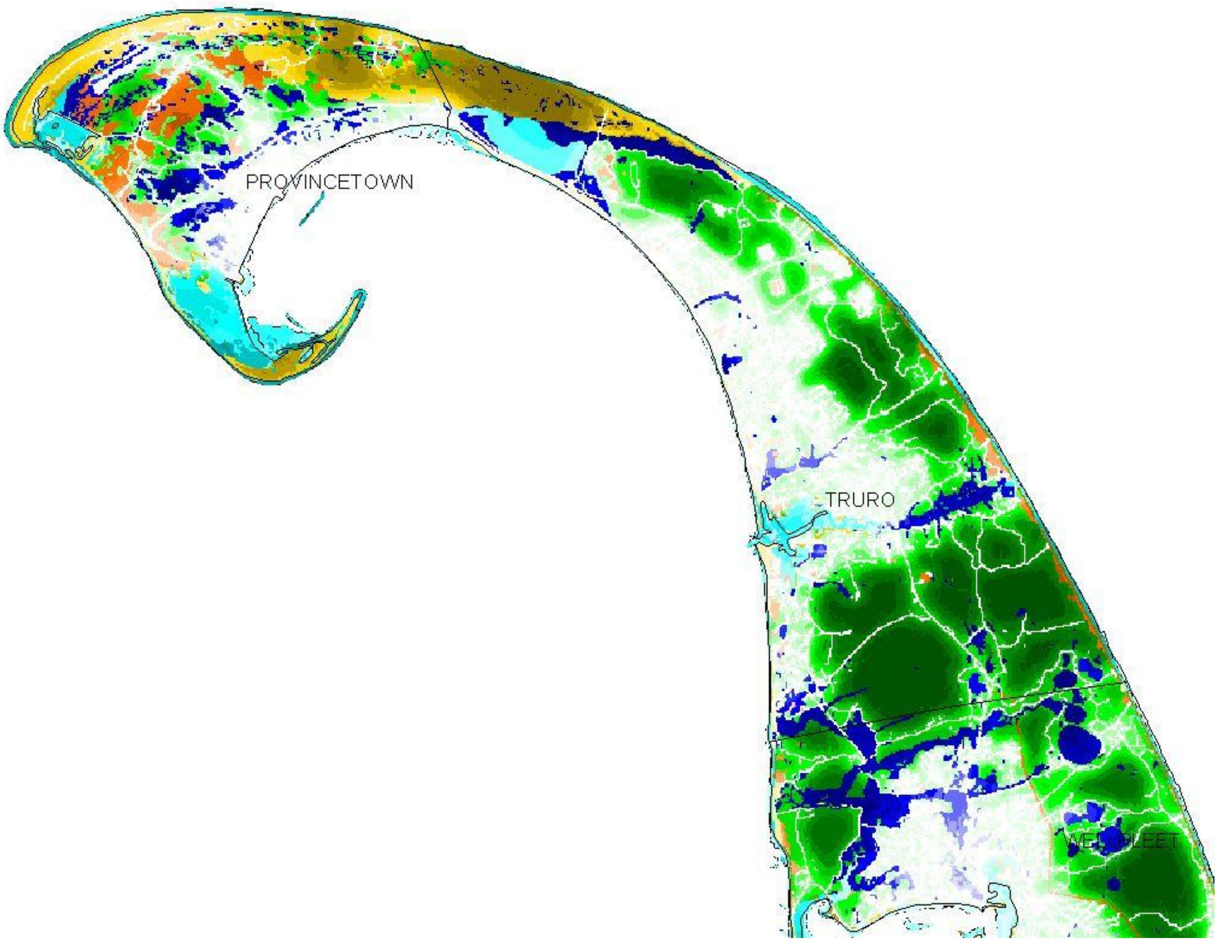

Fig. 7. Integrated IEI (IEI-I) for the towns of Provincetown and Truro depicted using a five-color scheme: forest (green), shrubland (orange), coastal upland (Yellow to brown), freshwater wetlands and aquatic (blue) and coastal wetlands (cyan). For all community types darker colors denote higher IEI scores.

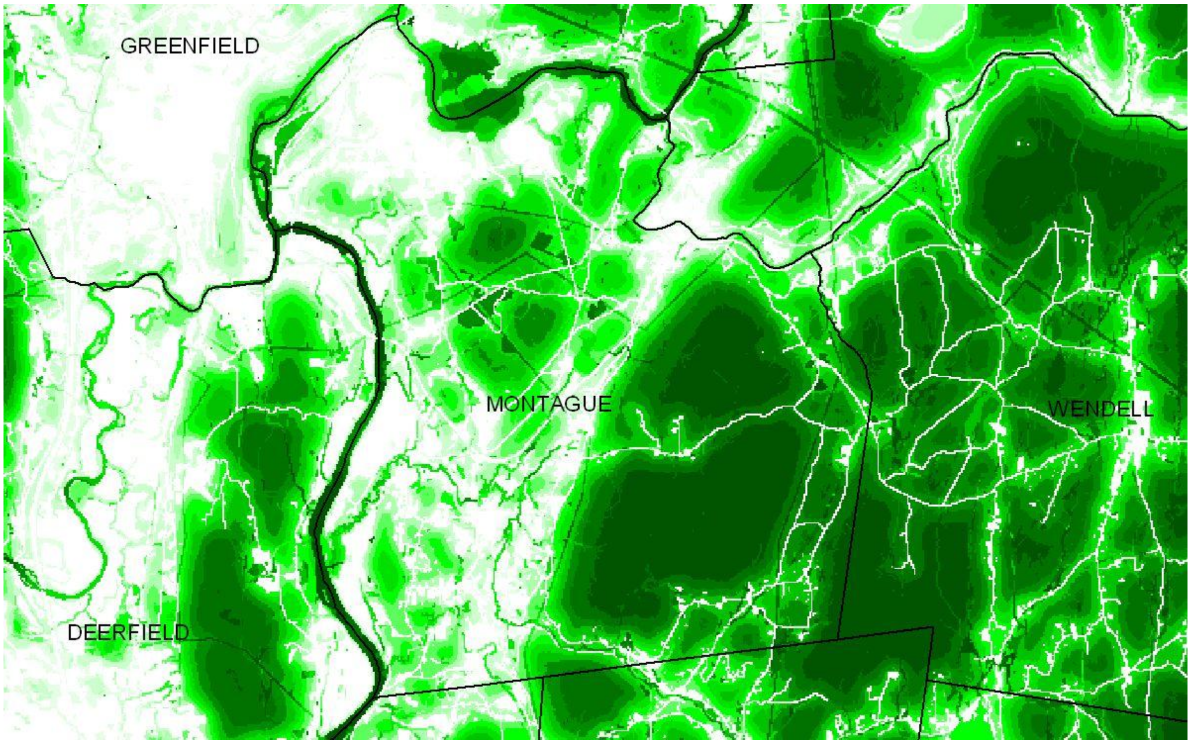

Fig. 8. Index of ecological integrity (IEI) for town of Montague, scaled to the entire project area (statewide). Darker areas denote higher IEI values; white areas are developed land.

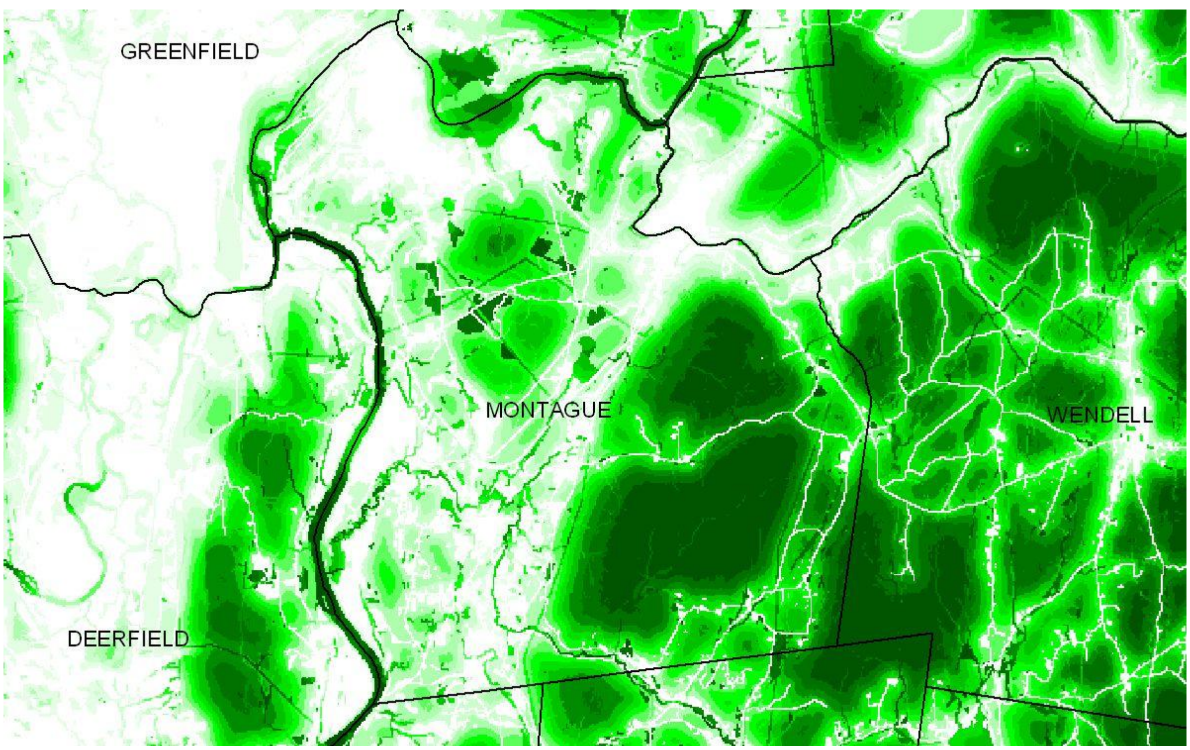

Fig 9. Index of ecological integrity for town of Montague, scaled by major watershed (IEI-W). Darker areas denote higher IEI-W values; white areas are developed land.

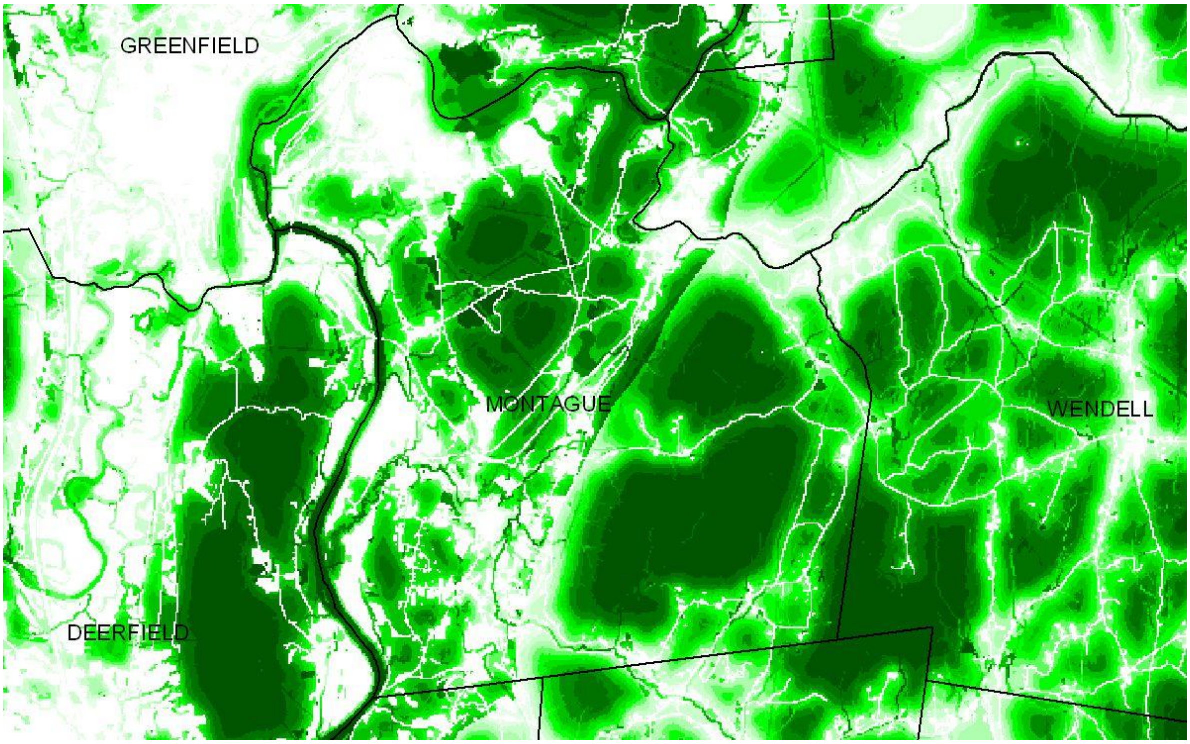

Fig 10. Index of ecological integrity for town of Montague, scaled by ecoregion (IEI-E). Darker areas denote higher IEI-E values; white areas are developed land.

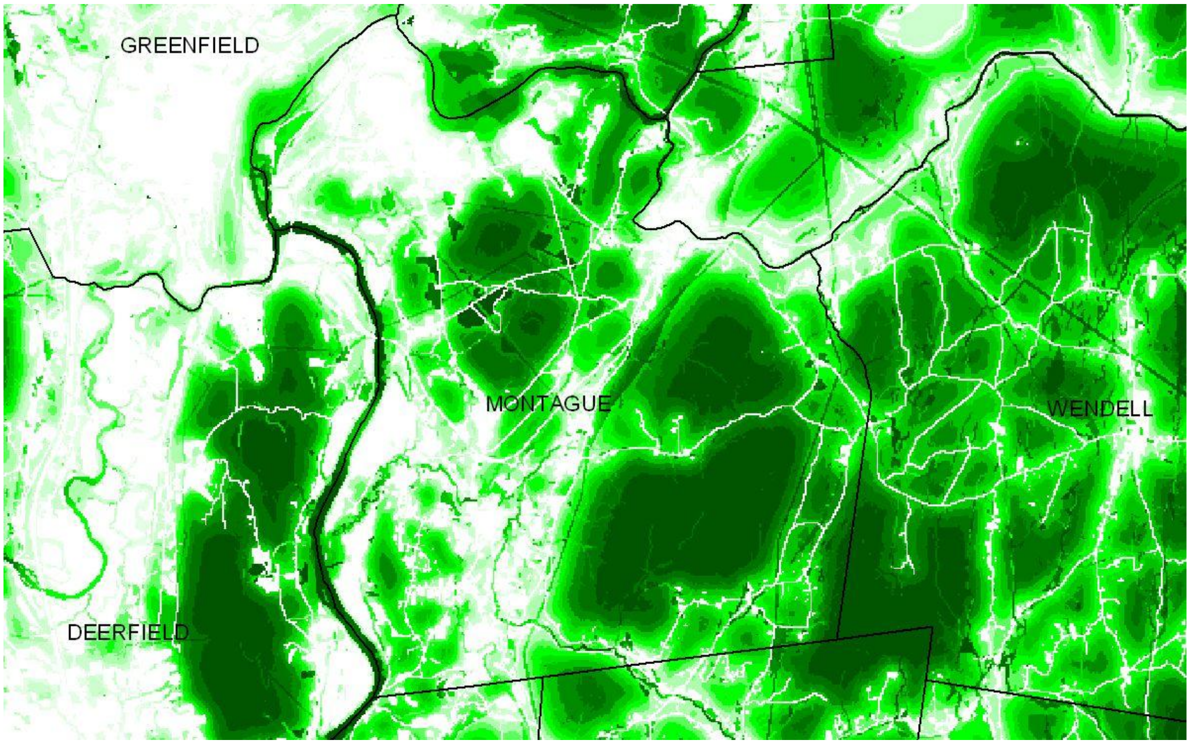

Fig. 11. Index of ecological integrity for town of Montague, integrated across full extent, watershed, and ecoregion (IEI-I). Darker areas denote higher IEI-I values; white areas are developed land.

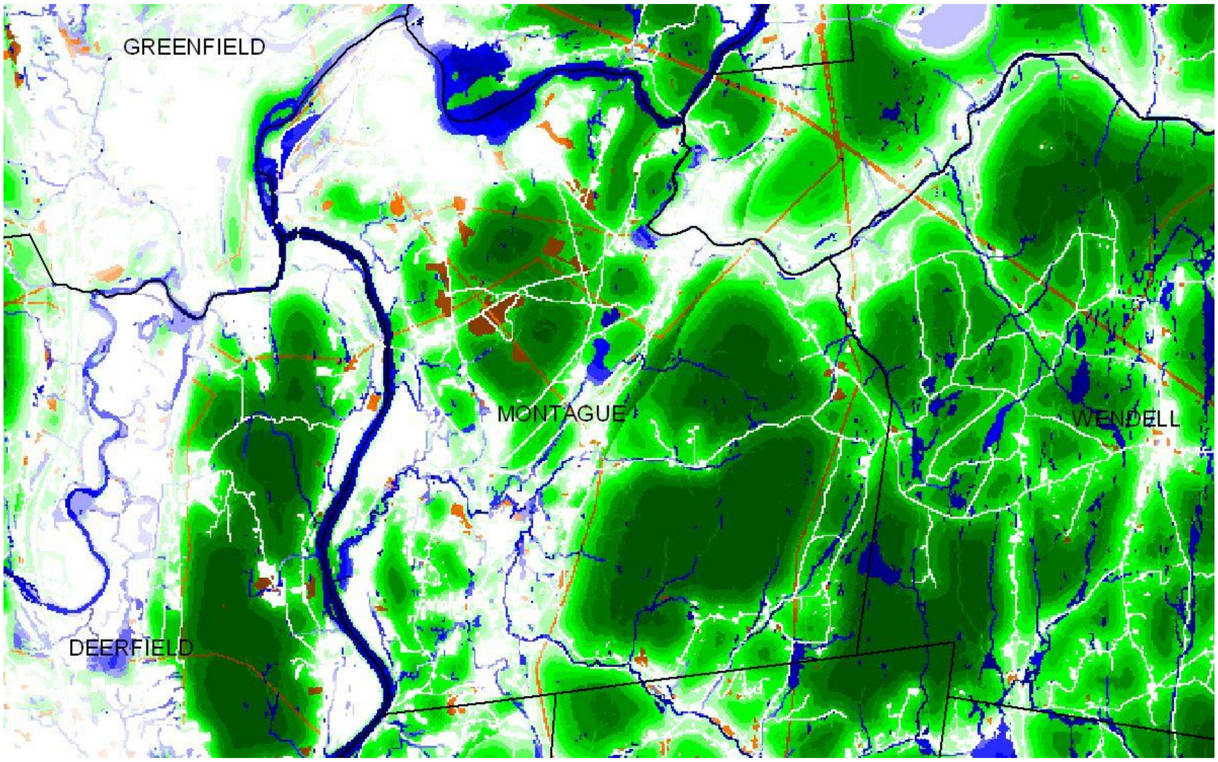

Fig. 12. Index of ecological integrity for town of Montague, integrated across full extent, watershed, and ecoregion (IEI-I) depicted using a five-color scheme: forest (green), shrubland (orange), coastal upland (yellow to brown), freshwater wetlands and aquatic (blue) and coastal wetlands (cyan). Darker areas denote higher IEI-I values; white areas are developed land.

High value areas that might be priorities for conservation can be highlighted by showing only those areas that fall in the top x% of IEI values, for instance the top 40% (IEI $\geq$ 0.60, Fig. 13). The "Important Habitat" maps produced for MassDEP use a 40% threshold. However, it is possible to view the CAPS results using other thresholds (e.g. top 10%, 25% or 50%).

Fig. 13. Integrated index of ecological integrity (IEI-I), top 40%. This image shows the 40% of land area with the highest IEI-I scores for each community.

Finally, individual metrics may be examined. The following images (Fig. 14-22) show the results of various CAPS metrics. Examining results of individual metrics can help users understand why areas were given a high or low IEI value, and can be used for specific purposes (e.g., identifying areas for water quality sampling or potential remediation/restoration).

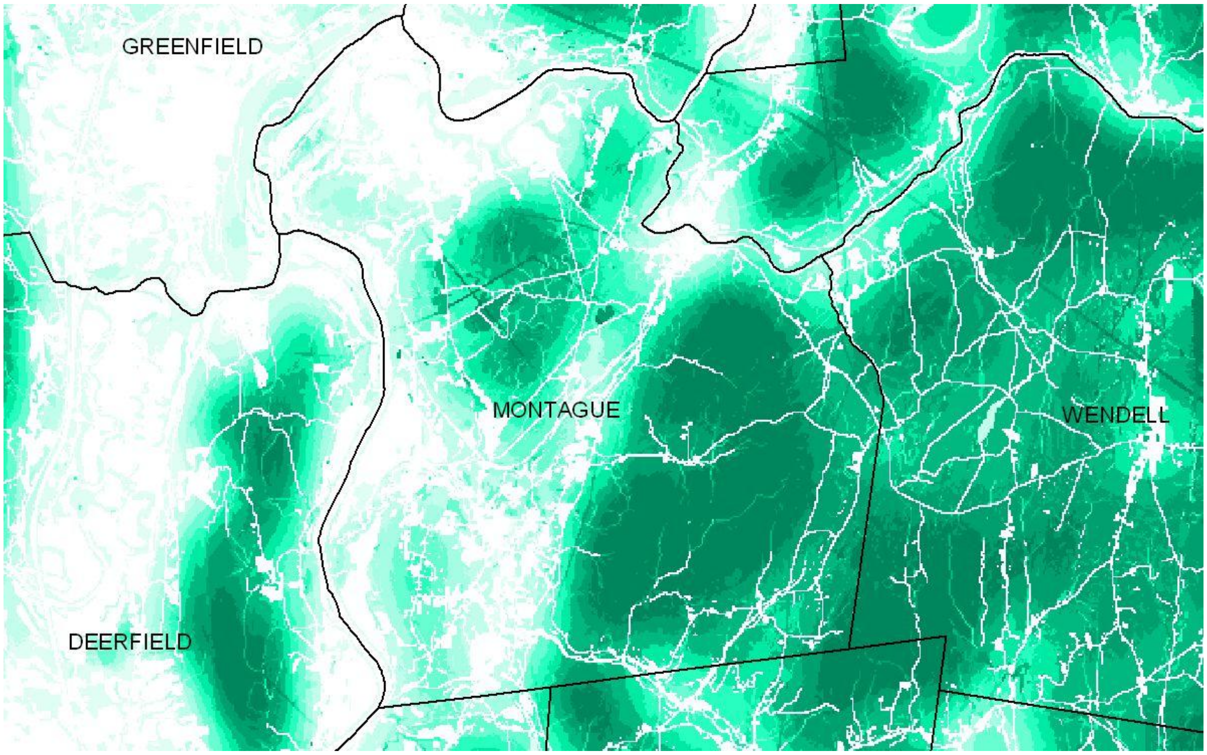

Fig. 14. Similarity metric for the town of Montague. Darker areas are those more similar to areas nearby in the landscape.

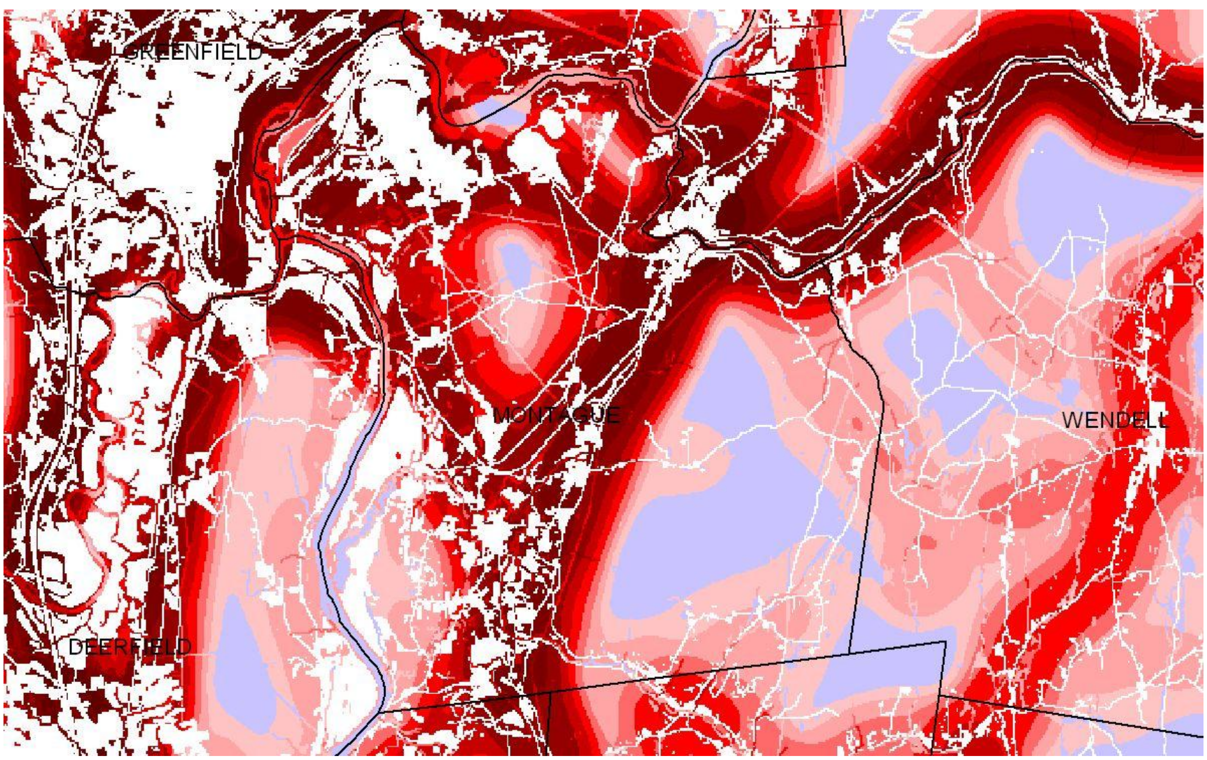

Fig. 15. Traffic intensity metric for the town of Montague. Areas in darker red are more highly impacted by road and railroad traffic. Blue areas are relatively unaffected by traffic. White areas are developed land.

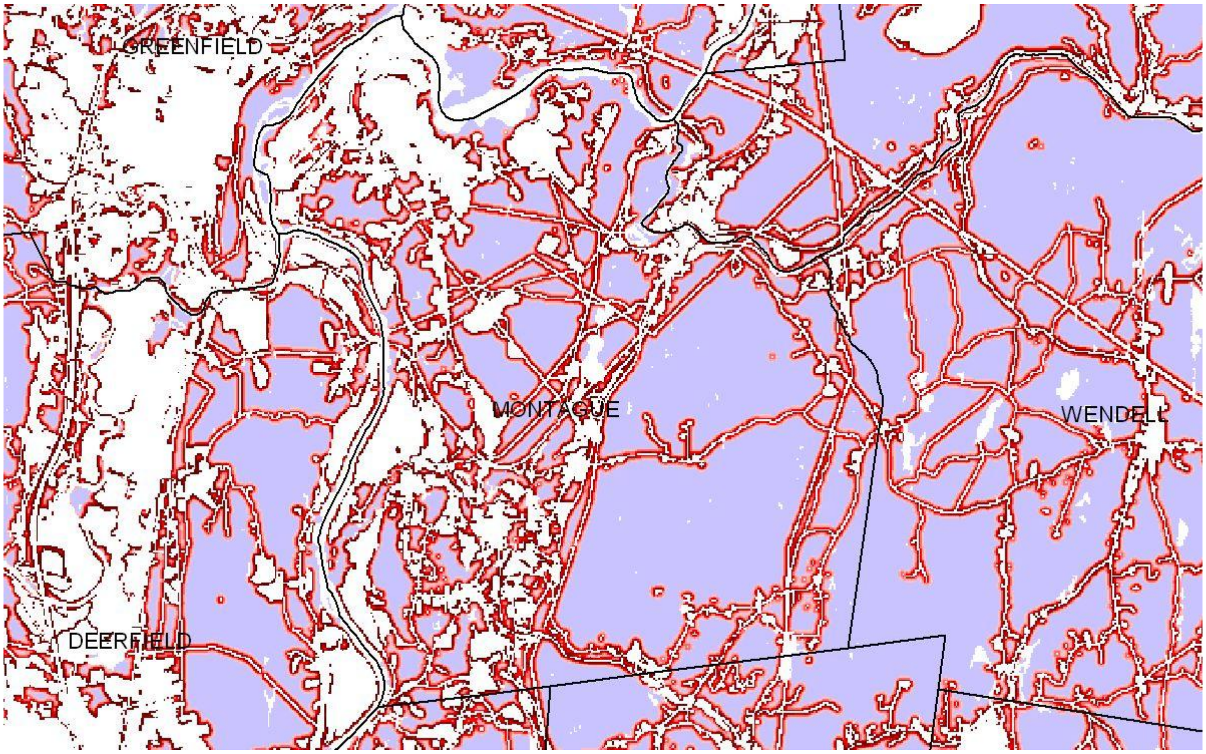

Fig. 16. Microclimate alteration metric for the town of Montague. Areas in darker red are more highly impacted by microclimatic alterations due to edge effects (e.g. decreased moisture, higher wind, and more extreme temperatures). Blue areas are relatively unaffected by traffic. White areas are developed land.

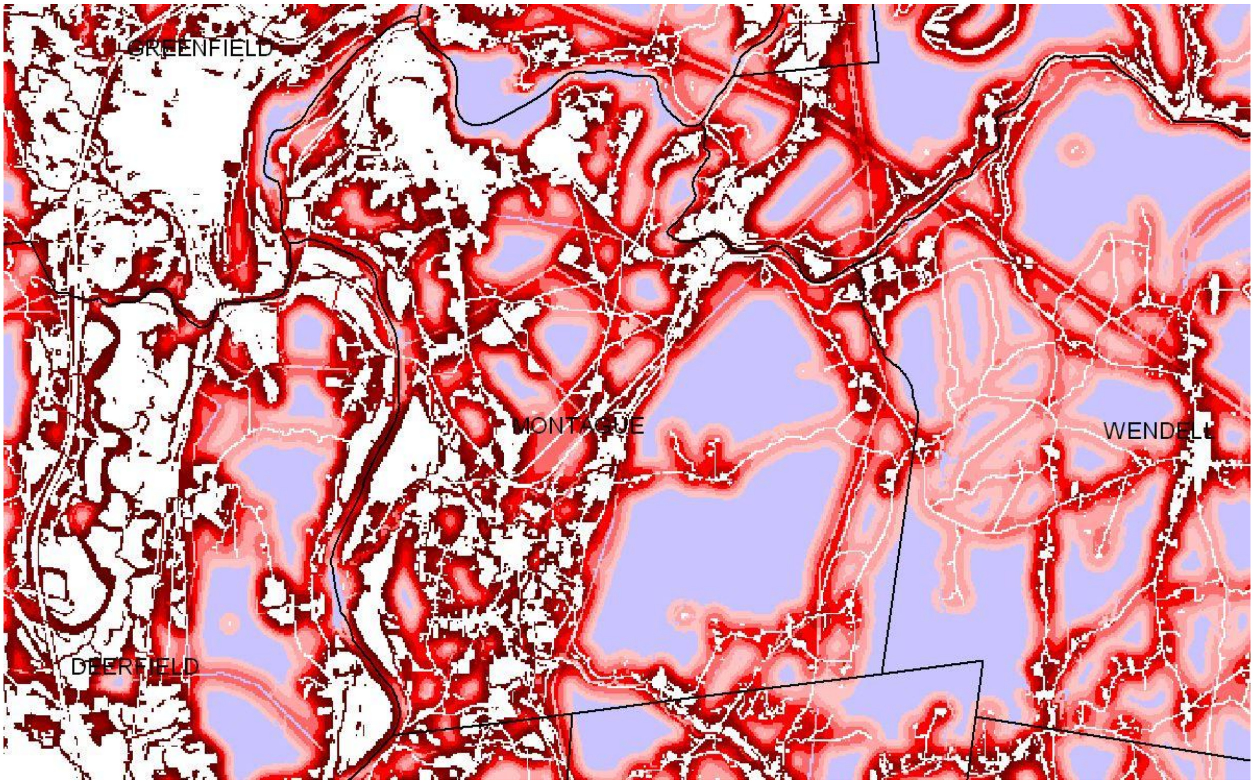

Fig. 17. Edge predator metric for the town of Montague. Areas in darker red are more highly impacted by edge predators (raccoons, skunks, opossums, foxes). Blue areas are relatively unaffected by edge predators. White areas are developed land.

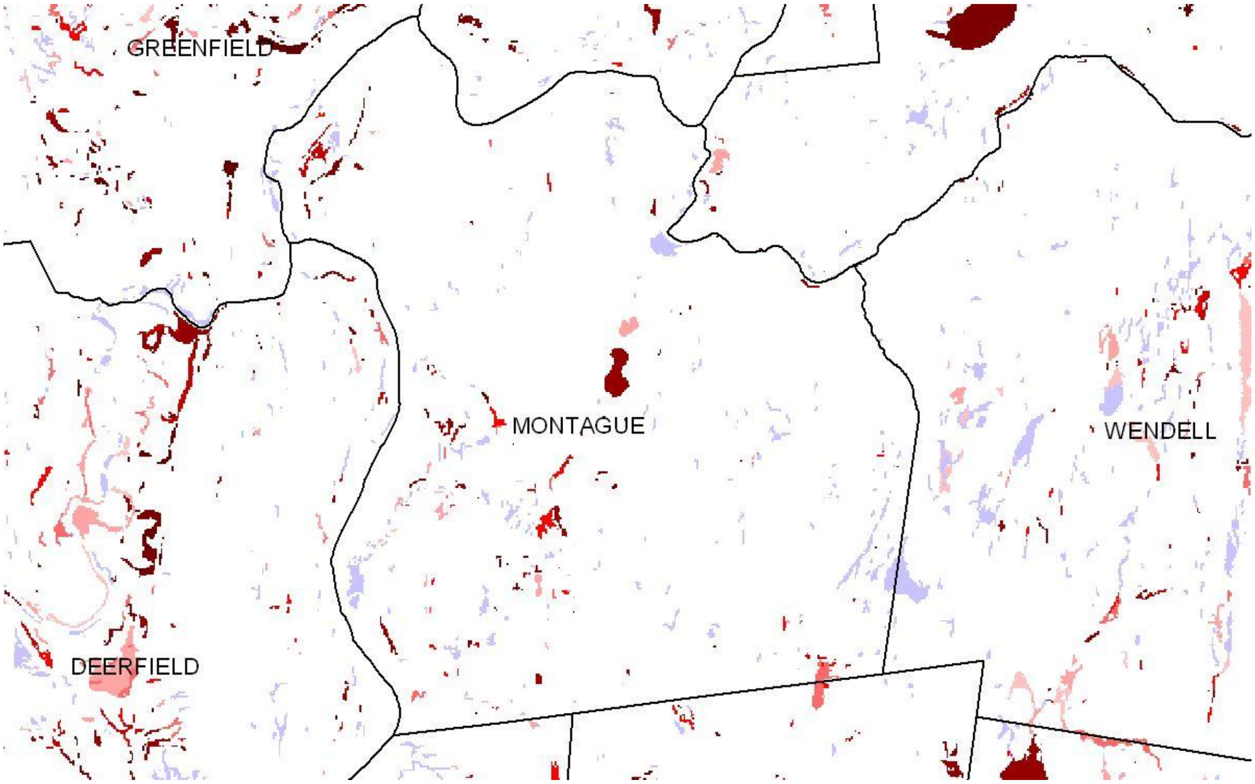

Fig. 18. Wetland buffer insults metric for the town of Montague. This metric is applied only to wetlands. Wetlands in darker red have a higher percentage of impervious surfaces in their 100-ft buffer zones. Blue areas are relatively unaffected by impervious surfaces within the buffer zone. White areas are non-wetland areas (uplands, streams and developed land).

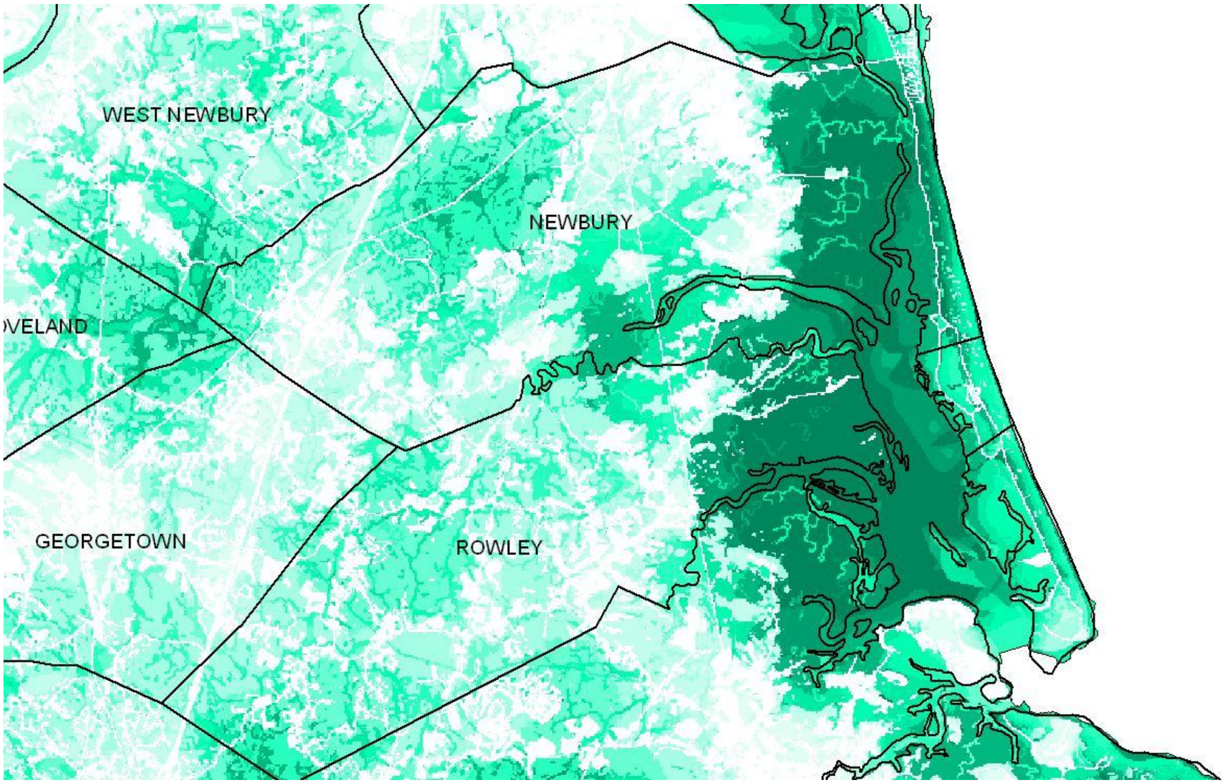

Fig. 19. Connectedness metric for an area on the north shore of Massachusetts. Areas in darker colors are more interconnected with similar areas nearby than those depicted in lighter colors. White areas are developed land.

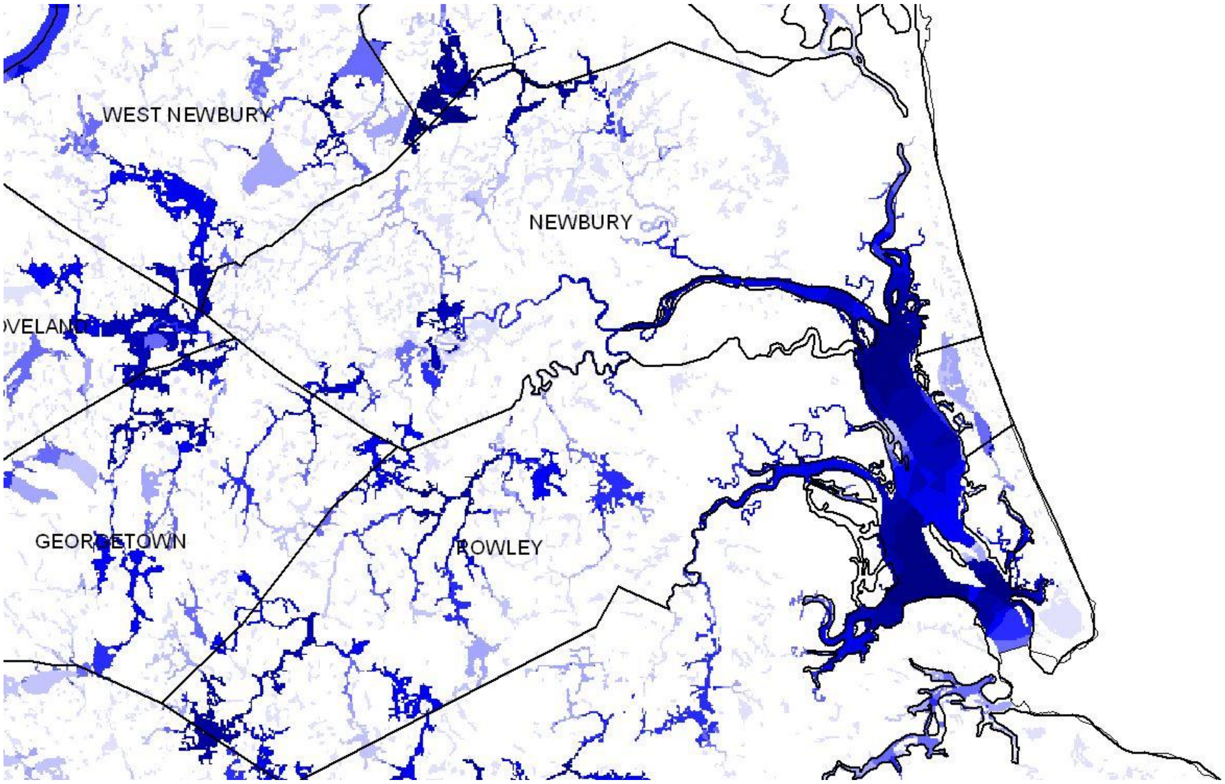

Fig. 20. Aquatic connectedness metric for an area on the north shore of Massachusetts. This metric is applied only to wetland and aquatic communities. Areas in darker blue are more interconnected with similar areas nearby than those depicted in lighter color. White areas are non-wetlands (uplands and developed land).

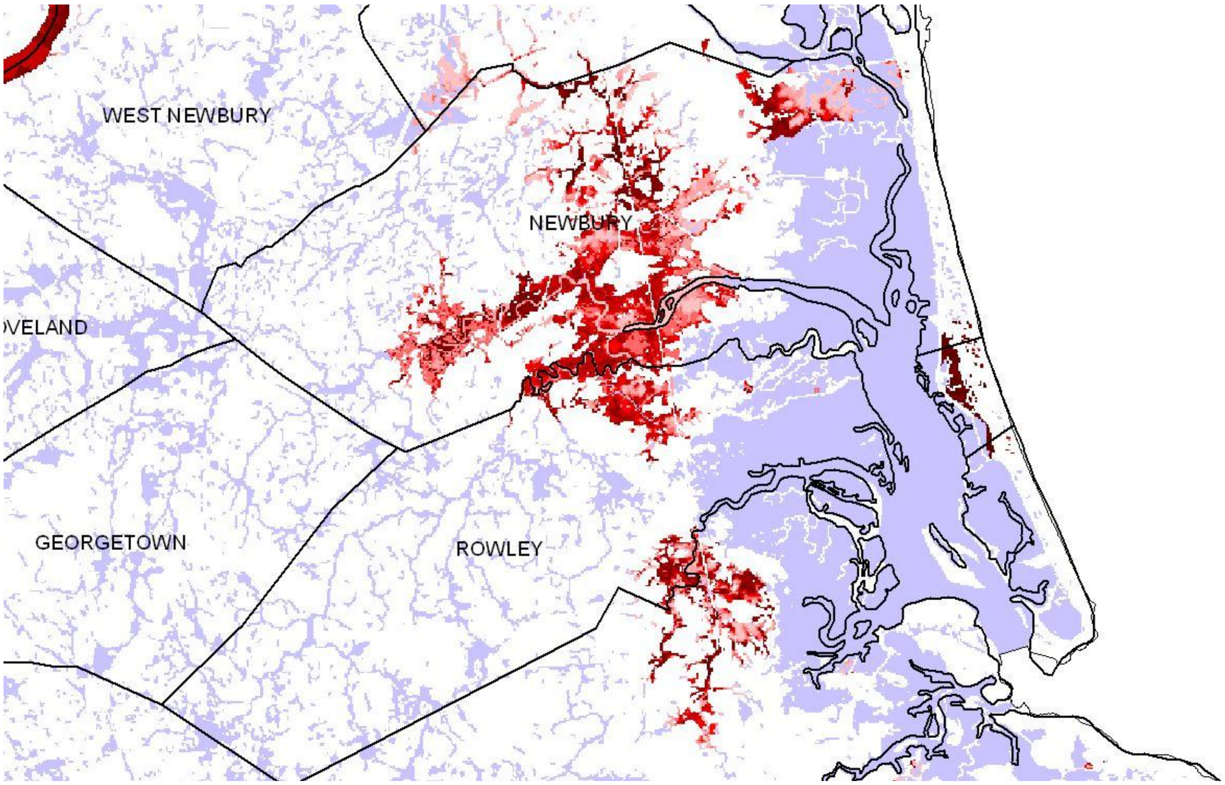

Fig. 21. Tidal restrictions metric for an area on the north shore of Massachusetts. This metric is applied only to wetland and aquatic communities. Areas in darker red are more highly impacted by tidal restriction. Blue areas are relatively unaffected by tidal restrictions. White areas are non-wetlands (uplands and developed land).

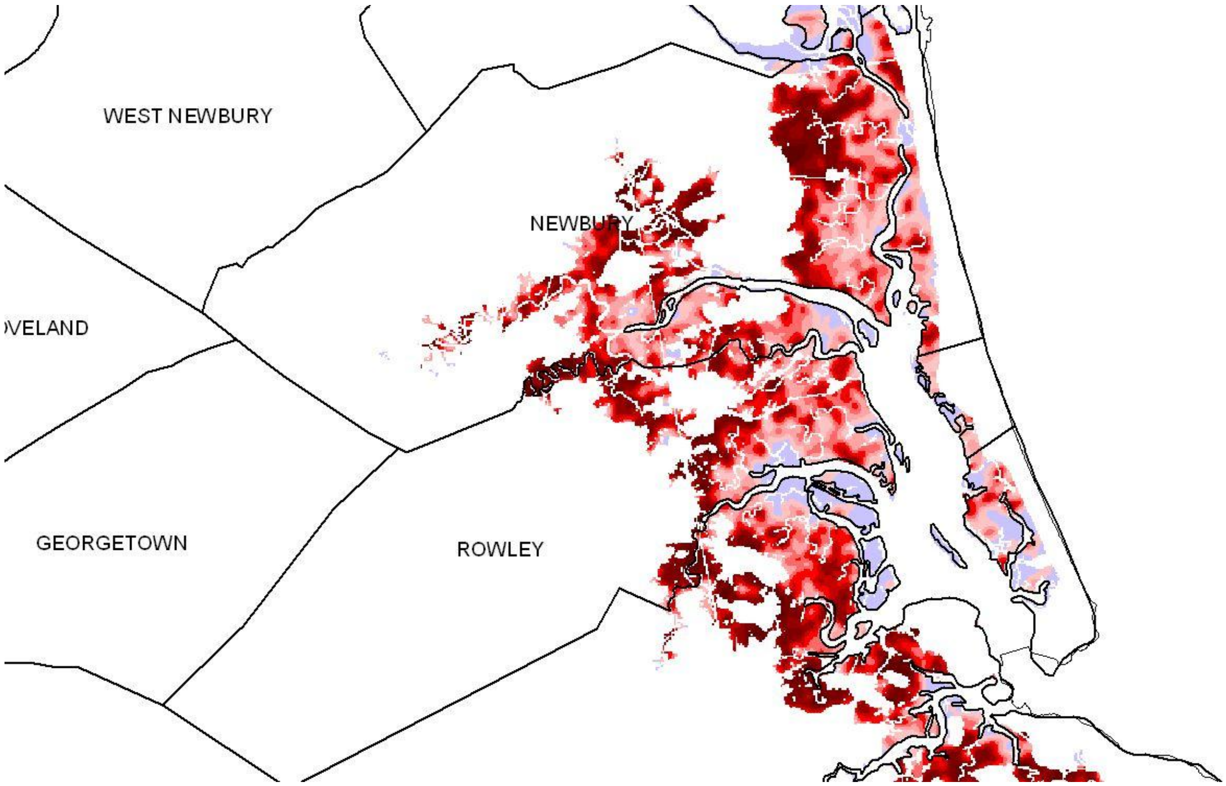

Fig. 22. Salt marsh ditching metric for an area on the north shore of Massachusetts. This metric is applied only to salt marshes. Areas in darker red are more highly impacted by ditching. Blue areas are relatively unaffected by salt marsh ditches.

Acknowledgements

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Appendix A: Changes to CAPS in this version

A large number of changes have been made to the CAPS data and software since the Spring 2009 preliminary statewide run. Here are highlights:

New metrics. A number of new coastal metrics have been implemented: salt marsh ditching, hardened beach structures, beach pedestrians, beach ORVs, and tidal restrictions. A new metric, aquatic connectedness, represents connectivity through the stream network.

Rewritten metrics. The connectedness metric has been changed to better reflect the inflow of organisms to a cell from the surrounding landscape. Connectedness also now uses models of terrestrial passability under bridges to better model the effect of road-stream crossings on connectivity (note that we have retained the original name despite the algorithm change; this updated metric was briefly called "isolation"). In addition, the watershed-based metrics (watershed habitat loss, road salt, road sediments, nutrient enrichment, imperviousness, and dams) have been completely rewritten and now reflect input across the entire watershed. Three old watershed metrics, point-source pollution, upstream road crossings, and percent impounded, have been dropped because data quality was poor or we weren't confident that they were meaningful.

Changes to cover types. There have been a handful of changes to the cover types, primarily consolidation of stream and coastal types into fewer classes. Extensive internal changes to the CAPS software reduce reliance on the land cover map, and make CAPS more flexible about mapping choices and more robust to mapping errors.

New settings variables. Several new settings variables have been added: terrestrial barriers, hard development, flow volume, stream gradient, calcium content, soil depth, pH, and texture, growing season degree days, minimum winter temperature, and solar exposure.

Changes to settings variables. Nearly all of the settings variables have been revised, many extensively. Of particular note, salinity now includes many brackish areas based on photo-interpretation, wetness has been completely revised to use terrain-based flow modeling, and aquatic barriers has been revised to use models of stream crossing scores based on extensive data collected for the Stream Continuity project.

Streams, flow, and hydrological modeling. We completely revised our terrain and hydrological modeling. The new version uses a more accurate Digital Elevation Model and a new approach to burning streams into the flow grid.

Road-stream crossings. We now base culverts, bridges, and tidal restrictions directly on vector roads and streams, resulting in considerably better accuracy and the ability link to empirical data on road-stream crossings and tidal restrictions. Aquatic and terrestrial road crossing scores are based on a statistical model using data collected as part of the Stream Continuity project.

Potential vernal pools that fell on top of road cells are now moved to the proper side of the road.

Aquatic mixing. A new system mixes results of aquatic metrics and settings variables across the width of rivers and throughout wetlands and waterbodies for more realistic results in these types.

New community models. Community models have been expanded to include new metrics and changed communities, and somewhat revised.

Changes to rescaling. In this version of CAPS, zeros are excluded from percentile rescaling, resulting in better differentiation among non-zero values from metrics with many zeros such as tidal restrictions or domestic predators, and giving scaled metrics that always run from 0 to 1. As a result, community models are applied more faithfully.

Appendix B: Input Data Layers

This section describes the source input data to CAPS, with a brief listing of major errors and limitations and of modifications we made to the data listed for each source. All data are the most recent available as of November 2011. Most of these data are available from MassGIS (http://www.state.ma.us/mgis/massgis.htm).

MassGIS 2005 land use – This is the source for developed land and some natural types in the landcover. Natural communities from land use include forest, powerline shrublands, and open land. We replaced wetlands and open water in this layer with those in DEP wetlands, which generally align and have higher thematic resolution.

- Water-based recreation is a mix of recreational beaches and associated parking lots and nearby forest, marinas, waterfront promenades, and even roads near beach parking lots.
- Transportation is a hodge-podge of freeway verges, train stations, airports, and highway garages.
- Urban public is a mix of urban hospitals, urban parks, office parks, etc.
- Saltwater sandy beach, which is mostly replaced by DEP wetlands (which breaks it into finer classes); will fill with nearest from DEP wetlands.
- Brushland/successional doesn't appear to be consistently and meaningfully different from open land; we lumped the two.
- Pasture and cropland are often confounded (some off this is real fluidity between these two uses, and much is probably mapping error). Additionally, hayfields are generally mapped as pasture, though the two are different ecologically.
- Cranberry bog polygons are much larger than those in DEP wetlands. They include intervening space around bogs: DEP wetlands mapped just the wet part, land use mapped the use. Land use is more up to date than DEP wetlands, so it maps many new bogs. We union the two and treat them as cranberry bog complexes. Additionally, abandoned cranberry bogs in Burrage Pond Wildlife Management Area are mapped as active cranberry bogs; we changed the class to shallow marsh/meadow/fen.
- We merged very low-density residential with low-density residential (this class isn't consistently applied and doesn't seem particularly meaningful).
- Note that unlike previous versions of Land Use, in this version developed areas are mapped fairly tightly to houses and yards, thus, for instance, wooded suburbs are generally mapped as blobs for individual houses rather than as one big polygon. This makes more sense for CAPS.

DEP wetlands – This is the source of our wetland and open water types, as well as some coastal uplands (beaches, dunes, etc.) DEP wetlands were photo-interpreted, and are generally of high quality, though they are somewhat dated. Beaver pond disturbance/succession has introduced many errors, in particular, current shrub swamps are often mapped as forested wetland.

- We split open water into lotic and lentic based on a model that used the shape of polygons to distinguish rivers from lakes and ponds, followed by thorough handchecking and editing. For post-processing, we further split lentic into lakes and ponds based on the size of the waterbody (ponds are < 5 ha). This was based on a logistic regression of sizes of lakes and ponds in the National Wetlands Inventory, because NWI distinguishes between lakes and ponds, whereas DEP wetlands depict all open water as one class.

- DEP wetlands were combined with Land Use for all analyses, except for Wetland Buffer Insults, which uses the original vector data for accuracy.

Potential vernal pools – We used photointerpreted Potential Vernal Pools from MassWildlife's Natural Heritage and Endangered Species Program.

- Potential vernal pools that fell within a terrestrial type were treated as a single pixel pool (30 m × 30 m). When a potential vernal pool fell within a wetland mapped by DEP, we retained DEP's classification.
- Because of the inherent difficulty of identifying vernal pools from aerial photography, this layer contains many errors of commission and omission. Because there is no other data source for this important community (certified vernal pools are still quite limited and highly biased by search effort), we used these data with caveats.
- We moved vernal pools that fell in the same cell as a road over one cell to fall alongside the road in our land use. We used an algorithm that looked at the vector data to move the pool to the correct side of the road.

MassGIS networked hydro centerlines, NHD stream network – We used the MassGIS networked stream centerlines for the mainland, and filled in the Cape and islands with edited versions of NHD centerlines.

- We edited these data to repair a significant number of breaks in the network, as the CAPS watershed metrics require a connected network.
- We deleted the dense (and meaningless) network of channels in cranberry bogs, instead connecting streams flowing through bogs with straight lines passing through the bogs. These dense channels made it impossible to represent flow in a 30 m grid.
- We deleted the ditches in salt marshes for similar reasons. Streams that flowed into DEP salt marshes were retained, and any stream that originated within a salt marsh was deleted.
- We extended stream mouths all the way to the ocean
- We added stream centerlines to our landcover grid in areas that were mapped as uplands to represent smaller (1st and 2nd order) stream communities
- We burned stream centerlines into the flow grid to force streams and rivers to prevent small DEM errors from misdirecting streams and rivers
- Because stream centerlines were digitized at varying densities, resulting in bias that affected our aquatic connectedness metric, we dropped all streams with a watershed of less than 30 ha. This has the effect of removing parts of the smaller headwater streams throughout, while making stream density more consistent.

MassGIS 5 m Digital Elevation Model – The DEM is the basis of several of our terrain-based settings variables, and of the flow used for our watershed metrics. We used the 5 m DEM because its accuracy, consistency, and overall quality was much higher than the older 30 m DEM and the DEM from the National Hydrography Dataset. We used the DEM to create a flow direction grid, the source of flow accumulation, $CaCO_3$, and watershed metrics. The DEM was also used to model tides and tidal restrictions, solar exposure, and the slope and gradient settings variables.

- We sampled this DEM up to 30 m for all analyses
- For flow modeling (flow-based settings variables and watershed metrics), we filled depressions in the DEM

Flow direction – The D8 (single-direction) flow direction grid was derived from the depressionless 30 m DEM. We then burned stream centerlines into the flow grid to ensure that stream and river beds are represented correctly. This was an iterative processes that entailed finding loops introduced by errors in stream centerlines, correcting them, and repeating the process. Flow direction is used for watershed metrics, and also for the $CaCO_3$ content settings variable.

Flow accumulation – We built a FD8 (multiple-direction) flow accumulation grid from the flow grid and DEM. This process allows a cell to flow to multiple downslope cells, giving much more realistic flow patterns in midslopes. Flow accumulation is used for the settings variables wetness and flow volume.

- We estimated the watershed area of streams flowing into Massachusetts from NHD's flow accumulation grid.

Aquatic resistance – We modified the approach of Randhir et al. 2001 (Forest Ecology and Management 143:47-56) to build a time-of-travel grid for each cell in the project area, based on land cover, slope, flow, and stream gradient. This grid was used to define the influence area within the watershed of each point for our watershed metrics.

Dams – Dams are from the Massachusetts Office of Dam Safety.

- Dams include a structural height, which we use as a surrogate for the hydrological disruption and aquatic barrier effect of each dam.
- Dam data are old with many quality issues.

Protected open space – We selected permanently protected open space (lev_prot = "P") from the MassGIS Protected and recreational open space layer. These data are used to adjust road traffic rates in parks and state forests.

Roads and road traffic – Roads and road traffic are from the MassDOT 1:5000 Roads layer (via MassGIS). Roads were reclassified into five types (expressway, primary highway, secondary highway, light duty road, and unpaved road) based on original road classes as well as surface type (for unpaved roads). For traffic rates, we used ADT, the annual average daily traffic, which MassDOT interpolated from measured traffic rates.

- Road linework and classes are generally very accurate. The primary issue is that many paper and discontinued roads are represented.
- Traffic rates are modeled from point data and thus suffer from considerable uncertainty. Traffic rates for larger roads are probably fairly accurate, as traffic on most major roads is measured on a regular basis. Unmeasured local roads are typically assigned a rate of 100 (or sometimes 200) cars/day, which is often a wild overestimate. Many of the smallest roads, including discontinued roads and new subdivision roads were assigned a traffic rate of 0. Many closed, gated, and discontinued roads were assigned traffic rates of 100. We made the following changes to traffic rates to improve their accuracy:
  - ❖ We set a minimum traffic rate of 10 cars/day for all zero-traffic roads
  - ❖ We changed the traffic rate for all unpaved and unknown type roads with traffic rates ≤ 200 that run through permanently protected open space to 10. This fixes the wild overestimates of traffic through parks and state forests such as Myles Standish, the Quabbin, and many other state forests and other large conservation areas.

Railroads – From the MassGIS trains layer. Railroads were mapped in three classes: railroad, abandoned railbed, and rail trail.

- We deleted linework where abandoned rails were shown underwater in the Quabbin, and where railroads run through major tunnels (the Hoosac tunnel)
- We integrated rail traffic into our traffic rates layer by assigning traffic rates for commuter, passenger, and freight lines, based on estimates of the number of cars for each railroad type, estimated average number of daily freight and commuter trains, and number of daily passenger trains from schedules, and expert team assignment of the relative impact of a train car to an automobile.
- We estimated the number of tracks in each rail line from GIS data for use in the terrestrial barriers settings variable.

Road-stream crossings – Bridge and culvert locations were estimated from the intersections of stream centerlines with road and railroad linework. For each crossing, we estimated both aquatic and terrestrial passability scores based on UMass Extension's Stream Continuity Project.

- Bridges and culverts on small, unmapped streams and unmapped roads are omitted.
- Bridges and culverts on streams with < 30 ha watersheds are omitted due to stream trimming.
- Crossing scores are based on a modeling approach with rather wide confidence intervals; furthermore, models of target scores are based on expert opinion rather than empirical passability data.
- Aquatic passability is used for the aquatic barriers settings variable.
- Terrestrial passability is used in the connectedness metric to allow connectivity under roads and railroads at stream crossings.

Tidal regime – Tidal regime is estimated from a logistic regression of DEP wetlands salt marshes vs. uplands from the DEM and interpolated tide range from 120 NOAA tide stations. This gives a grid depicting the expected tidal influence at each point. Tidal regime is used as a settings variable, and also as an input to the tidal restrictions metric.

Tidal restrictions – Potential tidal restrictions are identified from the intersection of stream centerlines in the coastal area with road and railroad linework. We modeled the severity of tidal restrictions based on 75 measured tidal restrictions from field work done by CZM and DEP using a regression of the ratio of the area of expected salt marsh above each restriction (areas where the tidal regime suggest salt marshes) to the area of salt marsh mapped by DEP above each restriction. This regression was applied to all potential tidal restrictions to estimate restriction height at each point.

- Many restrictions occur where there are no roads or railroads, for instance at tide gates; we were unable to capture such restrictions.
- The relationship between the hydrological height of a restriction and the magnitude of ecological effect is unclear; however, our regression uses a measure of ecological effect (loss of salt marshes) as our target.
- The regression was significant ($P < 0.001$), but it has only moderate predictive power ($r^2 = 0.41$).

Imperviousness – Impervious surfaces are from MassGIS's impervious surface layer, based on 2005 orthophotos. This layer is at 1 m resolution. For the imperviousness settings variable, we summarized these data to percent impervious in each 30 m cell.

- Sandy or rocky areas (especially gravel pits) are often misidentified as impervious.
- Roads were included in MassGIS's impervious surface layer, so all mapped roads are identified as impervious, including paper roads, unpaved roads, and discontinued roads.

Soils – Soil depth, pH, and texture are from NRCS digital soil maps. Most of these data were mapped at 1:25,000, but only low-resolution (1:250,000) data were available for Franklin and Plymouth counties.

- Soil texture was classified on an ordinal scale of 1-6, where 1 is organic, and 2-6 range from fine to coarse textured. Values were lumped from on text classes such as "silt loam" or "very fine sandy loam." Soil texture was not supplied for open water or urban areas.
- Soil pH was based on the representative pH for each soil type. pH values are fairly coarse, with missing values for urban areas, open water, and many other areas. Soil pH for Franklin County was dropped and left missing due to poor data quality.
- Soil depth is the expected depth to bedrock, dense, or cemented layers. We log-transformed soil depth for the soildepth settings variable. Soil depth is missing for open water and is set to zero for some mountainous areas and other apparently arbitrary areas.

Calcium – We used the geology field from TNC's Ecological Land Units for calcareous and moderately calcareous near-surface bedrock. (The original source for this dataset is USGS, available on MassGIS; TNC has reclassified lithology). Our $CaCO_3$ settings variable uses these values directly for terrestrial areas, and uses a flow accumulation model for wetlands and open water.

- Lithology is mapped at scales ranging from 1:100,000 to 1:500,000, so fine details and smaller inclusions are omitted, and spatially accuracy is poor.

Wind speed, wind power – Wind speed and power data are modeled by TrueWind Solutions LLC. Wind speed is available from MassGIS; we obtained wind power (in 16 cardinal directions) from the UMass Wind Energy Center. Original data are at 200 m resolution; we downsampled these data to 30 m by interpolation.

- Our wind exposure settings variable is based on wind speed at 30 m.
- The wave exposure settings variable uses directional window power at 50 m combined with reach to estimate potential wave exposure along the coast.

Salinity – Our salinity settings variable has three classes:

- Saltwater: areas mapped in DEP wetlands as ocean, tide flat, and rocky intertidal.
- Brackish: areas mapped in DEP wetlands as salt marsh, areas mapped as open water tidal, brackish, or salt pond (poly_code = 9) in DEP wetlands, and additional areas photointerpreted as brackish for this project by Mike McHugh at MassDEP.
- Freshwater: anything that's not saltwater or brackish.

Public beaches – MassGIS's marine beaches. Used for the beach pedestrians metric.

Beach off-road vehicles – Area where off-road vehicles congregate and park on beaches were mapped by Nathalie Regis and Mike McHugh at MassDEP for this project. Areas of intensive ORV use on beaches were mapped based on information from DEP and CZM personnel as well as photointerpretation of beaches in the MassGIS DPH marine beaches layer. These data are used for the Beach ORVs metric.

Recreational beach parking lots – Parking lots for access to recreational beaches were photointerpreted by Nathalie Regis and Mike McHugh at MassDEP for this project. All parking lots that appeared to serve recreational beaches mapped in the MassGIS marine beaches layer were delineated. Data were modified based on review by experts at MassDEP and CZM. These data are used for the beach pedestrians metric.

Salt marsh ditches – Ditches in salt marshes were photointerpreted for this project by Nathalie Regis and Mike McHugh. This layer is used for the salt marsh ditching metric.

Coastal structures – Seawalls, jetties, groins, bulkheads, revetments, and breakwaters were originally obtained for most of the Massachusetts coast in field surveys by CZM. These surveys omitted some areas where access was not feasible. Omitted areas were completed based on photointerpretation by Nathalie Regis and Mike McHugh using orthophotos and oblique aerial photography. Coastal structures are used in the coastal structures metric.

Minimum winter temperature, growing season degree-days – Temperature data were obtained by downscaling modeled PRISM weather data via interpolation. Data are 30 year normals centered on 1985.

- The minimum winter temperature settings variable is the minimum of the coldest day in January or February.
- The growing season degree-days settings variable is based on the sum of monthly mean temperatures above a threshold of 10˚ C and below a threshold of 30˚ C.

Ecoregions – EPA ecoregions for Massachusetts are from MassGIS. We modified these data slightly to include all coastal cells. Ecoregions are used for IEI rescaled by ecoregions (IEI-E) and integrated IEI (IEI-I).

Watersheds – Major watersheds are from MassGIS. We modified these data slightly to include all coastal cells. Watersheds are used for IEI rescaled by watersheds (IEI-W) and integrated IEI (IEI-I).

Appendix C: Landscape Metrics

This appendix describes the landscape metrics available in CAPS. These metrics are weighted and combined separately for each community, using the community model listed in Appendix F.

Metric name	Grid name	Description
Stressor Metrics		
Development & roads		
Habitat loss	habloss	Measures the intensity of habitat loss caused by all forms of development in the neighborhood surrounding the focal cell, based on a logistic function of Euclidean distance. *Data source*: landcover
Watershed habitat loss	whabloss	Measures the intensity of habitat loss caused by all forms of development in the neighborhood upstream from the focal cell, based on the aquatic distance from the focal cell using on a time-of-flow model. *Data source*: landcover, streams, flow direction, watershed resistance
Wetland buffer insults	insults	Measures the amount of impervious surface in the immediate vicinity of a wetland (within 30.5 m). *Data source*: DEP wetland polygons, raw imperviousness grid
Road traffic	traffic	Measures the intensity of road traffic (based on measured road traffic rates) in the neighborhood surrounding the focal cell, based on a logistic function of distance. *Data source*: landcover, traffic rates
Mowing & plowing	mowplow	Measures the intensity of agriculture in the neighborhood surrounding the focal cell, based on a logistic function of distance. This metric is a surrogate for mowing/plowing rates (which are a direct source of animal mortality). *Data source*: landcover

Metric name	Grid name	Description
Microclimate alterations	edges	Measures the adverse effects of induced (human-created) edges on the integrity of patch interiors; that is, factors that negatively intrude on the patch from its surroundings. The edge effects metric is based on the “worst” edge effect among all adverse edges in the neighborhood surrounding the focal cell, where each adverse edge is evaluated using a “depth-of-edge” function in which the “effect” is scaled using a logistic function of distance. *Data source*: landcover
Pollution		
Road salt	salt	Measures the intensity of road salt application in the watershed above an aquatic focal cell weighted by road class and the modeled “influence value” for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model This metric is a surrogate for road salt application rates. *Data source*: landcover, streams, flow direction, watershed resistance
Road sediment	sediment	Measures the intensity of road sediment production in the watershed above an aquatic focal cell weighted by road class (i.e., size, substrate, gradient) and the modeled “influence value” for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model. This metric is a surrogate for road sediment production rates. *Data source*: landcover, streams, flow direction, watershed resistance
Nutrient enrichment	nutrients	Measures the intensity of fertilizer application in the neighborhood surrounding the focal cell, based either on a logistic function of Euclidean distance or on the aquatic distance from the focal cell based on a time-of-flow model to development classes (primarily agriculture and residential land uses). This metric is a surrogate for fertilizer application rate. *Data source*: landcover, streams, flow direction, watershed resistance

Metric name	Grid name	Description
Biotic alterations		
Domestic predators	cats	Measures the intensity of development associated with sources of domestic predators (e.g., cats) in the neighborhood surrounding the focal cell, based on a logistic function of distance to development classes. This metric is a surrogate for domestic predator abundance measured directly in the field. *Data source*: landcover
Edge predators	edgepred	Measures the intensity of development associated with sources of human commensal mesopredators (e.g., raccoons, skunks) in the neighborhood surrounding the focal cell, based on a logistic function of distance to development classes. This metric is a surrogate for mesopredator abundance measured directly in the field. *Data source*: landcover
Invasive plants	badplants	Measures the intensity of development associated with sources of non-native invasive plants in the neighborhood surrounding the focal cell, based on a logistic function of distance to development classes. This metric is a surrogate for non-native invasive plant abundance measured directly in the field. *Data source*: landcover
Invasive earthworms	worms	Measures the intensity of development associated with sources of non-native invasive earthworms in the neighborhood surrounding the focal cell, based on a logistic function of distance to development classes. This metric is a surrogate for non-native invasive earthworm abundance measured directly in the field. *Data source*: landcover
Hydrological alterations		

Metric name	Grid name	Description
Imperviousness	imperv	Measures the intensity of impervious surface in the watershed above the focal cell, based on imperviousness and the modeled “influence value” for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model. *Data source*: landcover, streams, flow direction, watershed resistance, percent imperviousness
Dams	damint	Measures the number of dams in the watershed above an aquatic focal cell weighted by dam size and the modeled “influence value” for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model. *Data source*: landcover, streams, flow direction, watershed resistance, dams
Coastal metrics		
Salt marsh ditching	ditches	Measures the magnitude of temporal loss of open water habitat (i.e., loss of open water habitat during mid to low tides) around the focal cell due to ditching, based on a standard kernel density estimate of nearby drainage ditches. *Data source*: landcover, photo-interpreted salt marsh ditches
Coastal structures	jetties	Measures the proximity of the focal cell to up-gradient manmade jetty/groin, based on a logistic function of distance to nearest up-gradient jetty/groin; applied only to certain land cover types (e.g., beaches, intertidal flats). *Data source*: landcover, field-checked and photo-interpreted coastal structures
Beach pedestrians	beachpeds	Measures the intensity of beach pedestrian traffic at the focal cell, based on a standard kernel density of pedestrians. *Data source*: landcover, public beaches, photo-interpreted beach parking lots

Metric name	Grid name	Description
Beach ORVs	beachORVs	Measures the intensity of beach ORV traffic based on proximity of focal cell to ORV beaches. *Data source*: landcover, beach ORV parking areas
Tidal restrictions	tr	Measures the magnitude of alteration to the tidal hydrology of the focal cell due to tidal restrictions. *Data source*: landcover, tides settings variable, tide range, estimated tidal restriction points (road/stream and railroad/stream crossings), flow direction.
Integrity Metrics		
Connectedness	connect	Measures the disruption of habitat connectivity caused by all forms of development between each focal cell and surrounding cells as well as the "resistance" of the surrounding undeveloped landscape, as well as the similarity of surroundings. A hypothetical organism in a highly connected cell can reach a large area of ecologically similar cells with minimal crossing of "hostile" cells. This metric uses a least-cost path algorithm to determine the area that can reach each focal cell, incorporating each cell's similarity to the focal cell. *Data source*: landcover, ecological settings variables
Aquatic connectedness	aqconnect	An aquatic version of the connectedness metric, measuring connectivity along streams and rivers. Aquatic connectedness includes the resistance from culverts, bridges and dams for organisms that are primarily aquatic. *Data source*: landcover, streams, ecological settings variables
Similarity	sim	Measures the amount of similarity between the ecological setting at the focal cell and those of neighboring cells, weighted by a logistic function of distance. Similarity is based on the ecological distance between the focal cell and each neighboring cell, where ecological distance is a multivariate distance across all ecological setting variables. *Data source*: landcover, ecological settings variables

Appendix D: Ecological Settings Variables

This appendix lists the ecological settings variables. These 23 spatial variables are meant to represent the important ecological attributes of each point in the landscape. They were selected for their ecological importance, subject to data availability. These variables are used in the Similarity, Connectedness, and Aquatic Connectedness metrics. See Appendix G for their grid names, weights, and parameterization.

Biophysical attribute	**Biophysical variable**	**Description**
Temperature	Growing season degree-days	Degree-days is a heuristic tool for predicting vegetation growth; calculated by taking the sum of daily temperatures above a threshold (10°C). Temperatures above an upper threshold of 30°C are excluded. *Units & range*: 0-n °days *Source*: PRISM
	Minimum winter temperature	The minimum temperature (°C) reached in the winter sets the northern range limit for many plants and animals. *Units & range*: °C, unbounded *Source*: PRISM
Solar energy	Incident solar radiation	Solar radiation is a principal determinant of plant growth; calculated based on slope, aspect, and topographical shading. *Units & range*: arbitrary, unbounded *Source*: modeled from DEM and lat/long
Chemical & physical substrate	Soil pH	Soil pH measures acidity, which affects nutrient uptake by plants. *Units & range*: 0-14 pH *Source:* NRCS soils
	Soil depth	Soil depth (cm) affects communities primarily because shallow soils (usually on steep slopes or ridgetops) limit deep-rooted plants. *Units & range*: 0-n cm *Source:* NRCS soils

Biophysical attribute	Biophysical variable	Description
	Soil texture	Soil texture, ranging from organic soils through clay to gravelly sand affects plants and many soil-dwelling invertebrates and some vertebrates. *Units & range*: ordinal, 1 (organic) through 6 (coarse textured) *Source:* NRCS soils
	Water salinity	Salinity measures the salt content of water in aquatic settings and is an important determinant of the ecological community. *Units & range*: in three broad classes: fresh, brackish, and saltwater *Source*: from photo-interpretation (saltwater from DEP wetlands, brackish from DEP)
	Substrate mobility	Substrate mobility measures the *realized* mobility of the physical substrate, due to both substrate composition (i.e., sand) and exposure to forces (wind and water) that transport material, and is an important attribute of certain dynamic systems (e.g., coastal dune systems). *Units & range*: an index of mobility, ranging from 1 = stable to 10 = highly mobile *Source*: landcover
	$CaCO_3$ content	Calcium content of the soil and water influences buffering capacity (and hence susceptibility to acidification) among other things; calculated based on the composition of the soil and underlying bedrock. *Units & range*: % calcareous at cell (terrestrial) or % calcareous for the watershed (aquatic) *Source*: TNC's lithology (near surface bedrock)

Biophysical attribute	Biophysical variable	Description
Physical disturbance	Wind exposure	Wind exposure measures the exposure to sustained high winds, which can be an important determinant of plant community development under extreme conditions (e.g., Krumholtz vegetation on mountaintops); calculated based on the mean sustained wind speeds at 30 m above ground level using a 200 m resolution model developed for wind energy purposes. *Units & range*: meters per second *Source*: MassGIS wind speed data
	Wave exposure	Wave exposure measures direct exposure to ocean waves, which can influence physical substrate stability and hence plant community development. *Units & range*: index from none (no wave exposure) to maximum wave exposure (e.g., open ocean) *Source*: derived from custom GIS model that measures the average distance to land from a set of radial vectors emanating outward from the focal cell, scaled by the MassGIS wind power grid
	Steep slopes	Steep slopes measures the propensity for gravity-induced physical disturbance (e.g., talus slopes). *Units & range*: percent slope (0-infinite) *Source*: derived from DEM
Moisture	Wetness	Soil moisture (in a gradient from xeric to hydric). *Units & range*: arbitrary *Source*: Topographic wetness index, using FD8 algorithm, from DEM

Biophysical attribute	Biophysical variable	Description
Hydrology	Flow gradient	Gradient (percent slope) of a stream determines water velocity, often approximated by categories such as pool, riffle, run, cascade. *Units & range*: % slope, unbounded; 0 = flat *Source*: from DEM and MassGIS stream centerlines
	Flow volume (watershed size)	Flow volume measures the absolute size of a stream or river. This value is often approximated by stream order. *Units & range*: arbitrary; 0 for non-flowing systems *Source*: log-scaled FD8 flow accumulation, from DEM
	Tidal regime	In coastal areas, degree of tidal influence. *Units & range*: ranges from 0 for upland/inland areas beyond the reach of storm surges to 1 for areas with daily tides. *Source*: modeled from 5 m DEM, NOAA tide range data, and DEP wetlands
Vegetation	Vegetative structure	Coarse vegetative structure, from unvegetated through shrubland through closed canopy forest. *Units & range*: 1 to 10, ordinal *Source*: land use
Development	Developed	Indicator of development. *Units & range*: 0 = undeveloped; 1 = developed *Source*: land use
	Hard development	Indicator of mostly impervious development. *Units & range*: 0 = undeveloped or mostly pervious development (e.g. orchards, cemeteries); 1 = developed *Source*: land use

Biophysical attribute	Biophysical variable	Description
	Traffic rate	Traffic is based on a model of the probability of an animal crossing a road being hit given the traffic rate (see Gibbs and Shriver 2002, Conservation Biology 16:1647-1652). *Units & range*: 0-1 *Source*: MassDOT roads layer
	Impervious	Percent impervious surface. *Units & ranges*: 0-100% *Source*: MassGIS impervious layer, upscaled to 30 m
	Terrestrial barriers	Barriers to terrestrial organisms. *Units & ranges*: 0 to 5, expert-assigned *Source*: MassDOT roads, MassGIS trains
	Aquatic barriers	Barriers to aquatic organisms. *Units & ranges*: 0-1, values for dams, culverts, and bridges *Source*: MassDOT roads, MassGIS trains, MassGIS stream centerlines, Stream Continuity Project

Appendix E: Community Descriptions

This appendix lists the natural communities mapped and used in this version of CAPS. An index of ecological integrity is estimated for each of these communities (except ocean). Remember that IEI is scaled by comparing each cell in a community to other cells in the same community, thus IEI must be interpreted in terms of communities.

Note that developed types are all from MassGIS's 2005 land use layer and are not described here. Roads, railroads, abandoned railroads, rail trails, and dams are described in Appendix B, Input Data Layers, and not here.

Powerline shrubland – Powerlines from MassGIS 2005 land use. We did some GIS processing to ensure that narrow powerlines are continuous in our grid representation. Powerlines are one of the few shrubland communities in Massachusetts, and provide habitat for many early successional birds, plants, and insects, as well as nesting sites for several turtle species.

Open land – Open land is directly from MassGIS 2005 land use. The full description of this type is "vacant land, idle agriculture, rock outcrops, and barren areas. Vacant land is not maintained for any evident purpose and it does not support large plant growth." We assume that most areas mapped as open land provide habitat for early successional species.

Forest – This broad class of upland forests is directly from MassGIS 2005 land use.

Forested wetland – Forested wetlands are from DEP wetlands "wooded swamp" classes. We lumped their three classes (deciduous, mixed, and coniferous) because we didn't consider the distinctions to be consistently ecologically meaningful. We also lumped the barrier beach versions of these wetlands.

Shrub swamp – DEP wetlands shrub swamp and barrier beach-shrub swamp classes.

Bog – DEP wetlands bog and barrier beach-bog classes.

Shallow marsh – DEP wetlands "shallow marsh, meadow, or fen" and barrier beach-marsh.

Deep marsh – DEP wetlands deep marsh and barrier beach-deep marsh.

Vernal pool – This is from the Natural Heritage and Endangered Species Programs Potential Vernal Pools layer. We used this layer to capture small wetlands that were not mapped by DEP. We placed a one cell (30×30 m) vernal pool on any upland where a potential vernal pool fell, after moving potential vernal pool points out from under road cells for roadside vernal pools. Thus, our vernal pool community primarily represents small upland vernal pools.

Pond – Ponds are nonflowing unvegetated waterbodies < 5 ha.

Lake – Lakes are nonflowing unvegetated waterbodies > 5 ha.

Sea cliff – DEP wetlands "coastal bank, bluff, or sea cliff" class.

Vegetated dune - DEP wetlands "barrier beach system" class.

Coastal dune – DEP wetlands coastal dune and barrier beach-coastal dune.

Coastal beach – DEP wetlands coastal beach and barrier beach-coastal beach.

Salt marsh – DEP wetlands salt marsh and barrier beach-salt marsh.

Tidal flat – DEP wetlands tidal flat.

Rocky intertidal – DEP wetlands rocky intertidal shore.

Ocean – DEP wetlands “open water ocean” (poly_code = 10). Note that although ocean is a natural community, CAPS does not run metrics or build an IEI for ocean.

Salt pond/bay – Lentic waterbodies that coincide with “brackish” in the salinity settings variable.

Streams, by order and gradient – Streams are mapped by approximate order (first through fifth and higher) and gradient (low vs. high). Streams are derived from open water in DEP wetlands, which we split between lentic and lotic. Approximate orders are defined by selecting cutpoints of watershed area based on a series of logistic regressions to Strahler stream order from centerline data. All streams with watershed areas larger than the 5th order cutpoint were lumped. Gradient was split between low (flatwater, pool-riffle, plane-bed) and high (step-pool and cascade) at 3% gradient.

Estuaries, by order – Estuaries are mapped by order (but not gradient) using the same process we used for streams. Estuaries are derived from lotic open water that corresponds to “brackish” in the salinity settings variable.

Appendix F: Community Model Parameters

This table gives the community integrity models. The IEI for each community is a weighted combination of metrics selected by expert teams. Weights shown here are the percent contribution of each metric to each community (rounded to whole percent), thus rows sum to 100.

	Development & roads						Pollution			Biotic alterations				Hydro. alterations		Resiliency			Coastal				
	habloss	whabloss	insults	traffic	mowplow	edges	salt	sediment	nutrients	cats	edgepred	badplants	worms	imperv	damint	sim	connect	aqconnect	ditches	jetties	beachpeds	beach ORVs	TR
Forest	10			10		5				5	10	10	10			15	25						
Powerline shrubland	20			10						5	10	10	5			15	25						
Open land				15						8		15				23	38						
Forested wetland	9	4	4	9	4	4	4	4	4		4	9	4			9	17	2					9
Shrub swamp	9	9	9	9	5		5	5	5		5			5		9	16	2					9
Bog	10	10	10	5	5		10	5	10		5			5		10	19						
Shallow marsh	9	13	9	9	4		4	4	4		4			4		9	13	4					9
Deep marsh	9	13	9	9	4		4	4	4		4			4		9	13	4					9
Vernal pool	12			12	6		12	6	6		6			6		12	24						
Lake	9	18	9	5	5		5	5	9		5			5		9	9	9					
Pond	9	17	9	9	4		4	4	9		4			4		9	17						
Stream (1st)	10	5		5	5	5		5	5		5			10	5		10	20					10
Stream (2nd)	10	5		5	5	5		5	5		5			10	5		10	20					10
Stream (3rd)	10	10		5	5	5		5	5		5			10	5		5	24					10
Stream (4th)	10	10		5	5			5	5		5			10	10		5	24					10
Stream (5th)	9	14		5	5			5	5		5			9	9		5	23					9
Estuary (1st)	10	10		5	3			9	11	2	2			11	1	8	6	12					11
Estuary (2nd)	9	9		5	3			10	11	2	2			11	1	8	6	11					11
Estuary (3rd)	8	9		5	2			8	11	2	1			11	1	9	4	17					11
Estuary (4th)	8	8		5	2			7	12	1	1			10	3	9	4	18					11
Estuary (5th)	8	8		4	3			7	12	1	1			9	3	11	4	19					10
Sea cliff	16			8						10	7	15				21	24						
Vegetated dune	16			9	1					8	9	12				21	24						
Coastal dune	17			9						9	7	7				24	27						
Coastal beach	8			5						5	8	2				11	12			17	14	17	
Salt marsh	12		6	5	3					5	5					14	18		15				18
Tidal flat	20			5						2	8					30	35						
Rocky intertidal	17			2						6	10					33	31						
Salt pond/bay	21		7	5	1					3	4					30	30						

Appendix G: Settings Variable Parameters

This appendix lists ecological settings variables (described in Appendix D) with their GIS grid names and information on how they're used in the CAPS model. Ecological settings variables are used to determine resistance in Connectedness and Aquatic connectedness, and to determine ecological distance in Connectedness, Aquatic Connectedness, and Similarity. Settings variables are combined using the weights listed below for resistance and distance.

Settings variable	Grid name	Mixing[1]	Resistance	Distance
Temperature				
Growing season degree-days	degdays		0.3	1
Minimum winter temperature	mintemp		0.1	1
Solar energy				
Incident solar radiation	sun		0.1	1
Chemical & physical substrate				
Soil pH	soilph		0.05	0.5
Soil depth	soildepth		0.05	0.5
Soil texture	soiltex		0.05	0.5
Water salinity	salinity	inflows	4	3
Substrate mobility	substrate		2	2
CaCO3 content	calcium	inflows	0.1	1
Physical disturbance				
Wind exposure	wind		0.1	1
Wave exposure	waves		0.5	1
Steep slopes	slope		1	1
Moisture				
Wetness	wetness	inflows	4	8
Hydrology				
Flow gradient	gradient	pond	1	2
Flow volume	volume	sumlogs	5	5
Tidal regime	tides		2	2
Vegetation				
Vegetative structure	structure		3	8
Development				
Developed	developed		1	20
Hard development	hard		2	1000
Traffic rate	traffic		40	0
Impervious	imperv		5	0
Terrestrial barriers	tbarriers		15	0
Aquatic barriers	abarriers		100	0

[1] Settings variables may be mixed for water bodies and wetlands in several different ways:

inflows: all cells in a water body or wetland get the sum of inflowing values

sumlogs: the same as inflows for log-scaled variables

pond: all cells in a water body or wetland get the mean of all non-missing values

Appendix H: Landcover Grid Classification

The following are land cover classes used in the CAPS landcover grid.

1 Commercial
2 Industrial
3 Urban open
4 Urban public
5 Transportation
6 Mining
7 Waste disposal
8 Junkyard

10 Multi-family residential
11 High-density residential
12 Medium-density residential
13 Low-density residential

20 Spectator recreation
21 Participatory recreation
22 Golf
23 Water based recreation
24 Marina

30 Cropland
31 Cranberry bog
32 Nursery
33 Orchard
34 Cemetery
35 Pasture
36 Powerline shrubland
37 Open land

40 Forest
41 Forested wetland
44 Shrub swamp
45 Bog
46 Shallow marsh
47 Deep marsh
48 Vernal pool

55 Pond
56 Lake

60 Sea cliff
61 Vegetated dune
62 Coastal dune
63 Coastal beach

70 Salt marsh
71 Tidal flat
72 Rocky intertidal
74 Ocean
75 Salt pond/bay

81 Expressway
82 Primary highway
83 Secondary highway
84 Light duty road
85 Unpaved road

90 Railroad
91 Abandoned railbed
92 Rail trail

95 Bridge/culvert
96 Dam

111 Stream (1st) low
112 Stream (1st) high
121 Stream (2nd) low
122 Stream (2nd) high
131 Stream (3rd) low
132 Stream (3rd) high
141 Stream (4th) low
142 Stream (4th) high
151 Stream (5th) low
152 Stream (5th) high

211 Estuary (1st)
221 Estuary (2nd)
231 Estuary (3rd)
241 Estuary (4th)
251 Estuary (5th)

Appendix I: GIS Data Directory

Data organization. All CAPS results and many intermediate results are available for download. This section provides links to the various versions of IEI, the CAPS landcover, results of individual metrics, and settings variables. Data are available in grouped .zip files, listed below. In addition, individual metrics and settings variables are available in separate .zip files.

Data formats. With this release, we're supplying all grids as geoTIFFs as well as ESRI Arc grids. GeoTIFFs have several advantages over Arc grids: they are typically more space-efficient, they can be viewed in most image viewers and browsers as well as with GIS software, they can contain display formats intrinsically rather than requiring a separate application-specific legend, and most importantly, geoTIFF is a public domain format, as opposed to ESRI's proprietary format. As open-source GIS software (such as QGIS) becomes more sophisticated and stable, we anticipate many users will migrate to open source GIS. To support this migration, we plan to make our data available in public domain formats such as geoTIFF.

Scaling. Scaled metrics and IEI are scaled from 0-1; in geoTIFFs, these grids are expressed in terms of percent (scaled 0-100). Raw metrics and settings grids are scaled in original units, unique to each grid; in geoTIFFs, these grids are scaled from 0-255. The CAPS final landcover, capsland, represents landcover classes using integer classes (see Appendix H). GeoTIFF versions are already colored appropriately; legends files for QGIS, ArcView 3.3, and ArcMap are supplied for the Arc grid.

The coordinate reference system for all data is Massachusetts mainland State Plane, NAD83.

Basic results

These are the most basic results, for those who want immediate gratification. This .zip file consists of two files in geoTIFF format:

iei_i	CAPS Integrated IEI (scaled 1-100)
capsland	CAPS landcover grid

GeoTIFFs: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/basic.zip (17 MB)

Standard results

These results contain all four versions of the IEI, as well as landcover. In Arc grids, IEIs are scaled 0-1; In geoTIFFs, they are scaled 0-100.

iei	CAPS statewide IEI
iei_e	CAPS ecoregion IEI
iei_w	CAPS watershed IEI
iei_i	CAPS Integrated IEI
capsland	CAPS landcover grid

legend files for capsland (QGIS, ArcView 3.3, and ArcGIS)

GeoTIFFs: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/results.zip (66 MB)
Arc grids: http://jamba.provost.ads.umass.edu/web/caps2011/arczips/results.zip (104 MB)

Five color integrated IEI

The grid used to produce the IEI town maps ("areas of potential high ecological integrity") are available in a geoTIFF. This grid is the top 50% integrated IEI, displayed in five color gradients (green for forests, orange for shrublands, yellow-brown for coastal uplands, blue for freshwater wetland & aquatic, and cyan for coastal wetland aquatic). The values in this grid encode the color; they are not meaningful otherwise.

GeoTIFF: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/iei5color.zip (5 MB)

DEP important habitat

The DEP Massachusetts Habitat of Potential Regional and Statewide Importance data are available in a geoTIFF. This grid is simply the top 40% of integrated IEI (iei_i > 0.6); cells with a value of 1 are within DEP important habitat.

GeoTIFF: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/ieitop40.zip (8 MB)

Raw metrics

These .zip files contain all raw metrics results. See Appendix C for a list of metrics, grid names, and brief descriptions, and Appendix F for the contribution of each metric to each community's IEI. Raw metrics are scaled in original units, unique to each metric; geoTIFF versions are rescaled from 0-255. Integrity increases with decreasing values of stressor metrics, and increasing values of resiliency metrics.

GeoTIFFs: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/metricsraw.zip (157 MB)
Arc grids: http://jamba.provost.ads.umass.edu/web/caps2011/arczips/metricsraw.zip (760 MB)

Scaled metrics

These .zip files contain all scaled metrics results—these are the raw metrics rescaled by percentiles within each community. See Appendix C for a list of metrics, grid names, and brief descriptions, and Appendix F for the contribution of each metric to each community's IEI. Scaled metrics range from 0 to 1 (higher values correspond to higher integrity for all metrics); geoTIFF versions are scaled by percent (0-100).

GeoTIFFs: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/metricsscaled.zip (106 MB)
Arc grids: http://jamba.provost.ads.umass.edu/web/caps2011/arczips/metricsscaled.zip (169 MB)

Settings variables

These .zip files contain mixed (unscaled) settings variables. See Appendix D for a list and brief description of settings variables, and Appendix G for grid names and weights. Settings variables are scaled in original units, unique to each variable; geoTIFF versions are rescaled from 0-255.

GeoTIFFs: http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings.zip (85 MB)
Arc grids: http://jamba.provost.ads.umass.edu/web/caps2011/arczips/settings.zip (477 MB)

Individual grids

Metrics (both raw and scaled) and settings variables are also supplied as individual GeoTIFFs. These data are the same as those listed above; we're supplying grids individually for the convenience of those who just want results for a metric or two. Individual grids range in size from <1 to 18 MB.

Metrics

Development & roads

Habitat loss

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/habloss.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/habloss.zip

Watershed habitat loss

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/whabloss.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/whabloss.zip

Wetland buffer insults

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/insults.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/insults.zip

Road traffic

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/traffic.zip scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/traffic.zip

Mowing & plowing

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/mowplow.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/mowplow.zip

Microclimate alterations

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/edges.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/edges.zip

Pollution

Road salt

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/salt.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/salt.zip

Road sediment

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/sediment.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/sediment.zip

Biotic alterations

Domestic predators

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/cats.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/cats.zip

Edge predators

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/edgepred.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/edgepred.zip

Invasive plants

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/badplants.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/badplants.zip

Invasive earthworms

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/worms.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/worms.zip

Hydrological alterations

Imperviousness

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/imperv.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/imperv.zip

Dams

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/damint.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/damint.zip

Coastal metrics

Salt marsh ditching

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/ditches.zip
scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/ditches.zip

Coastal structures

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/jetties.zip scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/jetties.zip

Beach pedestrians

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/beachpeds.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/beachpeds.zip

Beach ORVs

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/beachORVs.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/beachORVs.zip

Tidal restrictions

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/tr.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/tr.zip

Resiliency Metrics

Connectedness

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/connect.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/connect.zip

Aquatic connectedness

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/aqconnect.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/aqconnect.zip

Similarity

raw: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsraw/sim.zip

scaled: http://jamba.provost.ads.umass.edu/web/CAPS2011/tiffzips/metricsscaled/sim.zip

Settings variables

Temperature

Growing season degree-days

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/degdays.zip

Minimum winter temperature

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/mintemp.zip

Solar energy

Incident solar radiation

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/sun.zip

Chemical & physical substrate

Soil pH

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/soilph.zip

Soil depth

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/soildepth.zip

Soil texture

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/soiltex.zip

Water salinity

http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/salinity.zip

Substrate mobility
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/substrate.zip
CaCO3 content
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/calcium.zip

Physical disturbance
Wind exposure
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/wind.zip
Wave exposure
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/waves.zip
Steep slopes
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/slope.zip

Moisture
Wetness
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/wetness.zip

Hydrology
Flow gradient
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/gradient.zip
Flow volume
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/volume.zip
Tidal regime
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/tides.zip

Vegetation
Vegetative structure
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/structure.zip

Development
Developed
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/developed.zip
Hard development
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/hard.zip
Traffic rate
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/traffic.zip
Impervious
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/imperv.zip
Terrestrial barriers
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/tbarriers.zip
Aquatic barriers
http://jamba.provost.ads.umass.edu/web/caps2011/tiffzips/settings/abarriers.zip

Additional data

A large collection of additional GIS data for Massachusetts are available from MassGIS (http://www.mass.gov/mgis/massgis.htm). Many of these data layers, such as town boundaries, ecoregions, watersheds, aerial photos, and USGS topographic maps are extremely helpful for viewing and interpreting CAPS results.

Running CAPS for Massachusetts requires a large number of additional intermediate data sources not linked above. These data are available on request.