University of Massachusetts Amherst
Conservation Assessment and Prioritization System (CAPS)
Index of Ecological Integrity

The University of Massachusetts Amherst Conservation Assessment and Prioritization System (CAPS) calculates an index of ecological integrity (IEI) for each point in Massachusetts by combining a variety of landscape metrics. These metrics include indicators of ecological quality such as nutrient loading in aquatic ecosystems, intensity of nearby road traffic, and effects of development on habitat connectivity, among many others. A distinct feature of the CAPS tool is its ability to compare the ecological consequences of various land use scenarios, such as the impacts of a development project or the benefits of ecological restoration, by comparing the loss or gain of IEI units among scenarios. CAPS researchers currently have pilot projects that apply IEI tools underway in Maine and Virginia and expect that CAPS will eventually be used in all North Atlantic states. However, the transferability of CAPS is limited by the fact that the software underlying CAPS software requires extensive GIS data, GIS expertise, and data processing capability.

OVERVIEW

Lead developer(s): Kevin McGarigal, Scott Jackson, Brad Compton, and Kasey Rolih, University of Massachusetts Amherst Landscape Ecology Lab.[1]

Year developed: 1999 with development ongoing.[2]

Geographic area: Currently the tool has only been applied within the state of Massachusetts, although multistate application is expected in the near future (Fig. 1).[2]

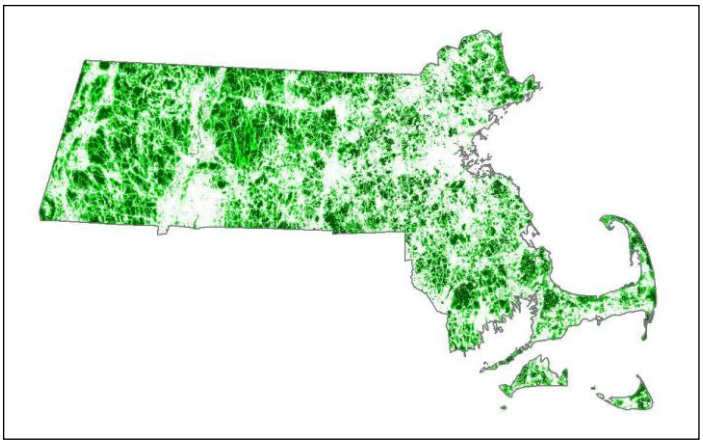

Figure 1. To date, the CAPS prioritization approach has only been applied within the state of Massachusetts, though broader applications are planned.

Resource types: CAPS evaluates 22 aquatic resource types: forested wetland, shrub swamp, bog, shallow marsh, deep marsh, vernal pool, lake, pond, streams (first through fifth order), estuaries (first through fifth order), salt marsh, tidal flat, rocky intertidal, and salt pond/bay.[2]

Restoration/conservation: CAPS prioritizes aquatic resource restoration (reestablishment or rehabilitation), creation, preservation/protection, and acquisition without preservation/protection.[2]

Stakeholders: Massachusetts Department of Environmental Protection, Office of Coastal Zone Management, Division of Fisheries and Wildlife, and Department of Transportation, in addition to regional planning agencies, The Nature Conservancy, Massachusetts Audubon Society, local land trusts and municipalities.[2]

PRIORITIZATION ANALYSIS

Input data QA/QC: Though the researchers put "considerable effort" into integrating data in ways that maximize accuracy, because CAPS input data come from a variety of sources, of variable quality, they expect that some amount of error will inevitably be present. The CAPS developers are unable to estimate the accuracy of the final dataset or effects that errors in the base map may have had on final results. The developers believe the effects of errors are negligible but plan to evaluate them in more detail in the future.[2]

Landscape prioritization tool(s):

Aquatic habitat IEI models: CAPS calculates IEI metrics for each of 22 different aquatic community types (listed above) that reflect the ability of each point on the landscape to support the ecosystem processes necessary for the long-term sustainability of biodiversity. Teams of experts – composed of federal and state agency scientists, NGO scientists, and academic scientists – calculate IEI scores for each community type using 20 submetrics (Table 1). Metrics are rescaled, weighted, and combined in various ways, depending on the community type, to score each $30m^2$ cell.[1]

The process of rescaling metrics involves assigning each metric score a new value between zero and one based on the relative percentiles for a given community – e.g., the best 10% of marshes for a certain metric receive values ≥ 0.90. Rescaling is critical as it accounts for differences in units of measurement and ranges of values across metrics and identifies the "best" of each community by eliminating bias in metric scores caused by more dominant communities (i.e., forest). After rescaling, the expert teams assign weightings to each metric based on a given metric's importance relative to other metrics for each community. The rescaled and weighted metrics are added together to obtain an overall IEI score.[1]

The geographic extent for which metrics are rescaled prior to the IEI calculation is critical for prioritizing different community types for conservation. If, for example, the metrics are rescaled relative to the boundaries of a watershed, then the top 10% of resulting IEI scores will identify areas likely to provide the highest ecological value over time within that watershed.[1]

Prioritization objectives assessed:[2]

- Habitat quality

Table 1. Factors used to calculate IEI scores for different community types and data sources from which they were derived.[1]

Factor used in analysis	Data source(s)
Development metrics	
Habitat loss	MassGIS 2005 land use and DEP wetlands
Watershed habitat loss	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM, watershed resistance
Wetland buffer insults	DEP wetland polygons, MassGIS impervious surface layer

Road traffic	MassGIS 2005 land use, DEP wetlands data, MassDOT traffic rate data
Mowing and plowing	MassGIS 2005 land use and DEP wetlands data
Microclimate alterations	MassGIS 2005 land use and DEP wetlands data
Pollution metrics	
Road salt	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM
Road sediment	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM
Nutrient enrichment	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM
Biotic alteration metrics	
Domestic predators	MassGIS 2005 land use and DEP wetlands data
Edge predators	MassGIS 2005 land use and DEP wetlands data
Invasive plants	MassGIS 2005 land use and DEP wetlands data
Invasive earthworms	MassGIS 2005 land use and DEP wetlands data
Hydrological alteration metrics	
Imperviousness	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM, MassGIS impervious surface layer
Dams	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, 30m DEM, Massachusetts Office of Dam Safety dams data
Coastal metrics	
Salt marsh ditching	MassGIS 2005 land use, DEP wetlands data, salt marsh ditches
Tidal restrictions	MassGIS 2005 land use, stream centerlines, and roads/railroads; DEP wetlands data, NOAA tide station data; 30m DEM
Integrity metrics	
Connectedness	MassGIS 2005 land use, DEP wetlands data; ecological variables*
Aquatic connectedness	MassGIS 2005 land use and stream centerlines, DEP wetlands data, NHD stream network, ecological variables*
Similarity	MassGIS 2005 land use, DEP wetlands, ecological variables*

NHD = National Hydrography Dataset, DEM = Digital Elevation Model, CZM = Coastal Zone Management. DEP = Massachusetts Department of Environmental Protection; NOAA = National Oceanic and Atmospheric Administration

* Ecological variables include: Growing season degree-days and minimum winter temperature (PRISM data); incidental solar radiation, steep slopes, wetness, flow volume, flow gradient, tidal regime (DEM data); soil pH, depth, and texture (NRCS soils data); water salinity (photo-interpreted); substrate mobility, vegetative structure, developed land, traffic rate, impervious, terrestrial barriers, aquatic barriers (land cover data); $CaCO_3$ content (TNC lithology data), wind exposure (MassGIS windspeed data), wave exposure (MassGIS wind power data); flow gradient (MassGIS stream centerlines), tidal regime (NOAA tide range data), tidal regime (DEP wetlands).

Calibration of the landscape priorities tool(s): CAPS researchers are seeking to calibrate their model with intensively collected data by comparing Index of Biological Integrity (IBI) scores obtained on the ground using site level assessment methods (SLAMs) with IBI scores derived from IEI scores. This approach will allow the researchers to determine whether sites are actually more degraded than their landscape prioritization models are indicating, thus informing possible changes in the model.[2]

Validation of the landscape prioritization tool(s): The CAPS team considered the use of Rapid Assessment Methods (RAMs) to validate their landscape prioritization model to be problematic because the RAMs are essentially unsophisticated models based on field data. Because validating based on RAM data would essentially mean verifying one model based on another and because a sophisticated landscape prioritization assessment might be expected to perform better than a RAM, the team decided solely to apply a landscape prioritization approach.[2]

Refinement of landscape priorities: The CAPS model provides information about the ecological benefit that can be expected if a site is restored, but provides no information about the feasibility of restoration at the site. After identifying a site using CAPS, users must complete field-based assessments to determine whether restoration is feasible.[2]

Prioritization products: A wide variety of maps that depict the prioritization of areas in terms of IEI and Important Habitat areas are available as pdfs at: http://umasscaps.org/data_maps/index.html. From this link, high resolution maps that rank the top 50% of $30m^2$ pixels in terms of IEI score for all cities and towns in Massachusetts and identify areas within the state containing Important Habitat are available for download as PDF documents (e.g., Fig. 2). In addition, ArcGIS and georeferenced TIFF (geoTIFF) files are also available for Important Habitat and IEI results for a variety of scales (e.g., watershed; see Fig. 3) and for a variety of underlying metrics (e.g., aquatic connectivity; see Fig. 4), at: http://jamba.provost.ads.umass.edu/web/caps2011/CAPS2011data.htm. Both Arc grid and geoTIFF data are accessible using GIS software, with geoTIFF also accessible using image viewers and web browsers. GIS data are produced as 30m resolution raster files.

A comprehensive CAPS Technical Guide will be available in the near future that will provide in-depth discussion of the conceptual underpinning, model verification, and calculation of individual metrics used by the CAPS approach.[2]

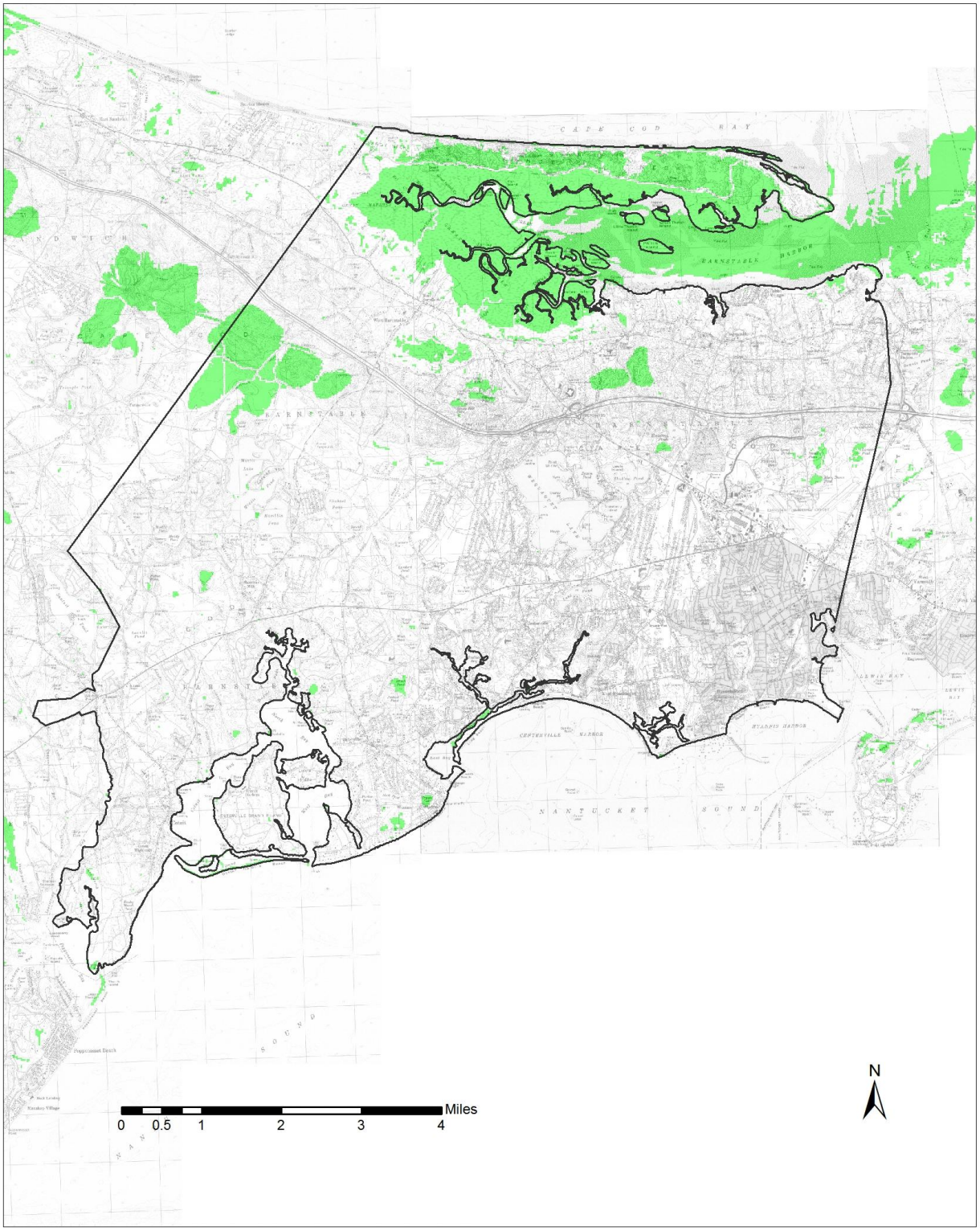

Figure 2. High resolution map showing areas considered to be "Habitat of Potential Regional or Statewide Importance." The IEI scoring system used to select the shaded areas was specially designed to meet specifications for regulatory review by Massachusetts Department of Environmental Protection under the Wetlands Protection Act. Used with permission from Massachusetts CAPS.

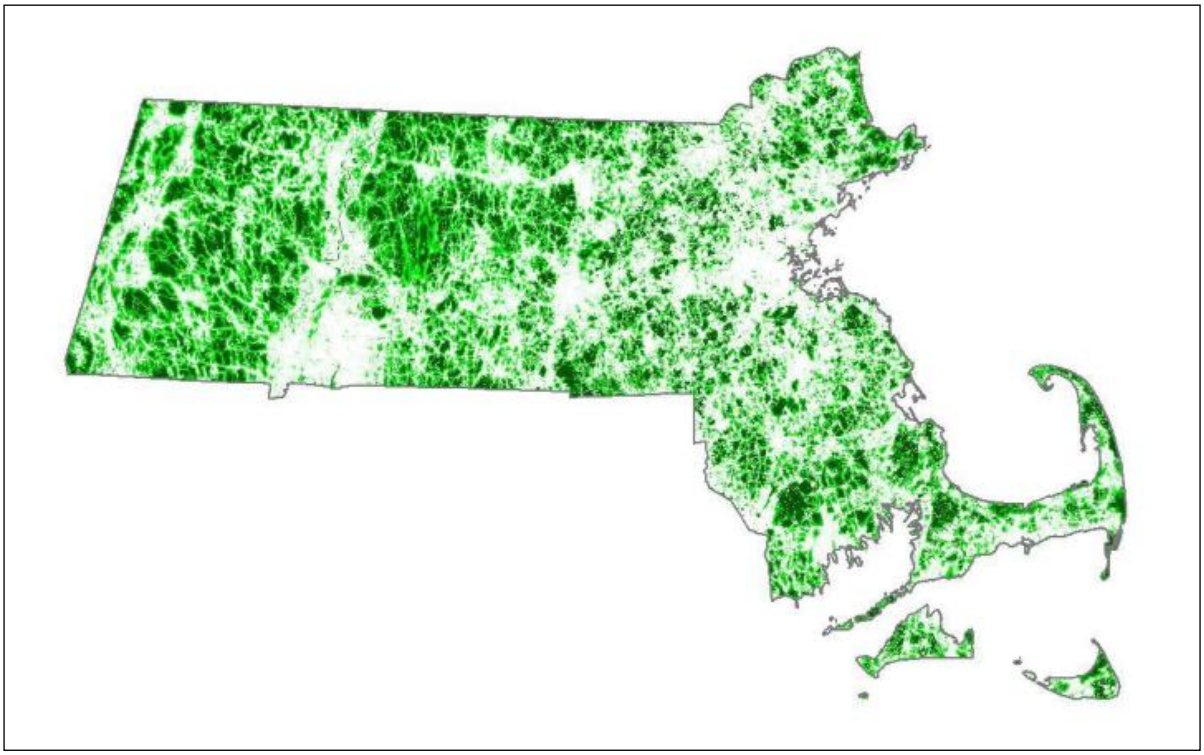

Figure 3. UMass Amherst CAPS makes Arc grid and geoTIFF files available that scale IEI scores by watershed for natural communities (forest, shrubland, freshwater wetland and aquatic, coastal wetland, and coastal upland) throughout Massachusetts (darker green = higher IEI rank). Used with permission from Massachusetts CAPS.

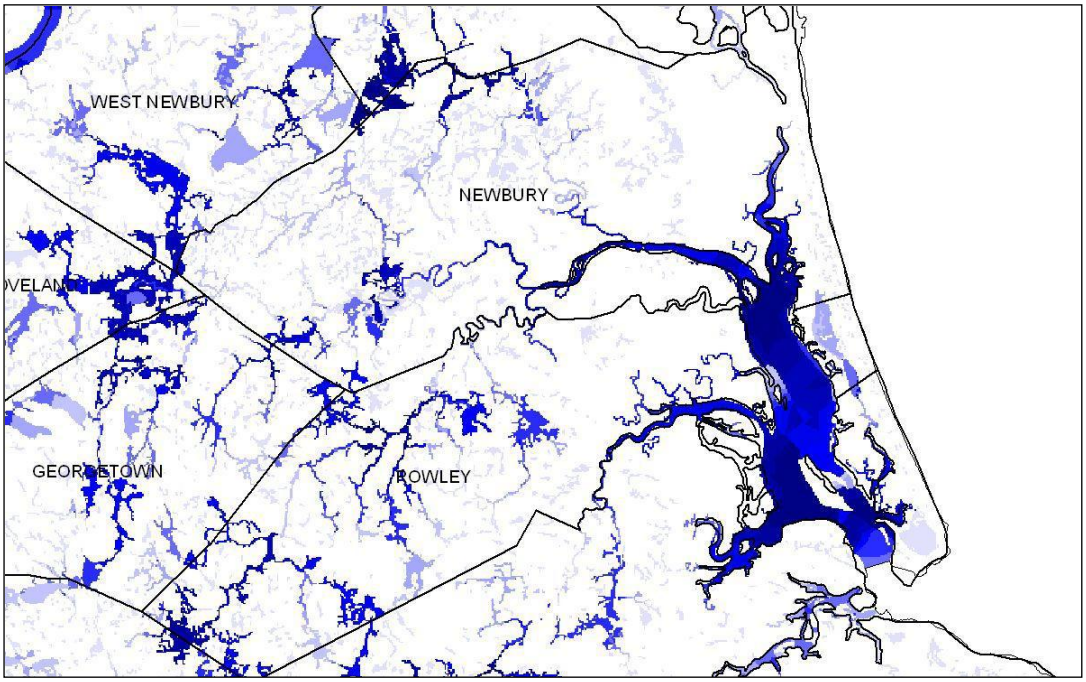

Figure 4. On its website, UMass Amherst CAPS makes Arc grid and geoTIFF data files available for individual metrics. For example, the data output for the aquatic connectedness metric, which ranks wetland and aquatic communities in terms of their interconnectedness with similar areas (darker blue = more interconnected), is available for download. Used with permission from Massachusetts CAPS.

IMPLEMENTATION

Regulatory/non-regulatory programs:

- Section 404 compensatory wetland mitigation:
  - Watershed approach to mitigation: CAPS is capable of determining IEI scores for a wide range of scales, including the watershed scale. Measuring IEI scores for a variety of communities within a watershed could provide coarse information about the quality of different ecological communities and inform the setting of priorities using a watershed approach. In addition, rescaling metrics so that IEI scores for aquatic community types are calculated by watershed (e.g., Fig. 3) may be useful for implementing the watershed approach to mitigation.
  - Informs the development of mitigation plans.[2]
  - Determining permit and monitoring requirements for wetland mitigation sites.[2]
- State wetland regulations: CAPS plays an important role in determining whether proposed wetland impacts should trigger regulatory review by the Department of Environmental Protection (DEP). It does so by determining areas containing "Habitat of Potential Regional and Statewide Importance" ("Important Habitat"). In the future, the CAPS representative expects that "Important Habitat" maps will be fully incorporated into state wetlands regulations.[2]
- NEPA alternatives analysis.[2]
- Prioritizing land conservation (the BioMap 2 project).[2]
- Analyzing route alternatives for the proposed South Coast Rail project.[2]
- Evaluating culvert replacement scenarios to compare ecological benefits of culvert removal.[2]
- Evaluating ecological benefits of dam removal.[2]
- Evaluating potential benefits for wildlife of constructing wildlife passage structures across road, railroad, and highway segments.[2]
- Evaluating the environmental benefits of specific restoration projects.[2]
- The U.S. Fish and Wildlife Service Landscape Conservation Cooperatives Program.[2]

Transferability:

- Under the U.S. Fish and Wildlife Service Landscape Conservation Cooperatives Program, UMass Amherst is currently adapting its IEI tool for use in other states. UMass Amherst researchers currently have pilot projects underway in Maine and Maryland and expect the IEI to eventually be used in all North Atlantic states.[3]
- The transferability of CAPS is limited by the fact that the modeling approach underlying the tool is sophisticated and that using CAPS software requires extensive GIS data, GIS expertise, and data processing capability. Only sophisticated GIS users can use the software.[2]

Data gaps:

- The quality of existing Digital Elevation Models (DEMs) limits what CAPS is able to do. In some cases, the developer has created metrics, only to throw them out later because the DEM quality was insufficient.[2]
- Field assessments of road-stream crossings.[2]

- Field-based data on severity of tidal restrictions.[2]
- Data on dams (height, characteristics).[2]
- Data on locations and effectiveness of fish passage structures.[2]
- Data on natural barriers to aquatic organism passage (e.g. waterfalls).[2]
- Data on location of water pollution sources (point-source discharges, stormwater outfalls) and quantity of pollutant discharged, especially for nutrients.[2]
- Data on location of water withdrawals and discharges including amounts of water withdrawn or discharged.[2]
- Data on water temperature for rivers and streams.[2]
- Data on groundwater contributions to stream flow and coastal wetlands in the glaciated coastal plain.[2]
- Location of areas of development that rely on on-site wastewater treatment (e.g. septic systems) as well as areas that are sewered.[2]
- Location of areas of development that rely on private wells as well as those areas served by a public water supply.[2]
- Data on water salinity for tidal rivers and streams (transition from salt to brackish to fresh).[2]
- In some cases, data that could fill these gaps exist but are not in a format that would be easy to use (e.g., point source discharges, water discharges, water withdrawals). The developer reports that they are currently working to get these data sources into the correct format.[2]

Barriers:

- Computer processing power and time: There is never enough time to do all that can be done with CAPS.[2]
- Funding: Though CAPS has been pretty successful at acquiring funding, more funding would certainly allow them to do more.[2]

Future goals:

- Make the metrics more based on empirical data.[2]
- Integrate landscape prioritization results with intensive assessment methods for more wetland types.[2]
- Make CAPS available for broad use by a wide range of people/agencies/organizations and in multiple states.[2] Obstacles cited by the developer to achieving this goal include:
  - GIS data are inconsistent from state to state.
  - Limitations in the capabilities and affordability of computer processing power
  - The large time and resource demands required to develop and deploy good intensive methodologies. Completing intensive methodologies on the cheap could jeopardize the quality of data or its interpretation.
- The developer cited data, money, and staff as resources that could help them achieve these goals.[2]

[1] McGarigal K, Compton B, Jackson S, Plunkett E, Rolih K, Portante T, Ene E. 2012. Conservation Assessment and Prioritization System (CAPS) Statewide Massachusetts Assessment: November 2011.

[2] Interview on 7/29/2011 with Scott Jackson, Program Director, UMass Extension's Natural Resources and Environmental Conservation Program, Department of Environmental Conservation, University of Massachusetts, Amherst.

[3] Feedback received on 6/14/2012 from Scott Jackson, Program Director, UMass Extension's Natural Resources and Environmental Conservation Program, Department of Environmental Conservation, University of Massachusetts, Amherst.