Cape Cod Salt Marsh Assessment Project:
Developing Measures of Condition

Grant Report Volume 1, August 2004

Investigation 1:
Relationship of salt marsh Indices of Biotic Integrity to surrounding land use, 1999

Prepared by:
Massachusetts Office of Coastal Zone Management

CZM

Prepared for:
US Environmental Protection Agency, Region I

EPA United States Environmental Protection Agency

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Prepared by:
Massachusetts Office of Coastal Zone Management
251 Causeway Street, Suite 900
Boston, MA 02114

Prepared for :
US Environmental Protection Agency, Region I
1 Congress Street, Suite 1100
Boston, MA 02114

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CZM
CZM INFORMATION LINE (617) 626-1212
CZM WEB SITE www.mass.gov/czm

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Background

Massachusetts Office of Coastal Zone Management (MA-CZM), in cooperation with project partners, has completed the U.S. Environmental Protection Agency (EPA) funded portion of a salt marsh assessment project in Cape Cod, Massachusetts. The project is comprised of two different investigations:

1. A single season comparison of salt marsh indicators from sites with varying surrounding land uses (Grant Report Volume 1), and
2. A multi-year comparison of indicators from tide restricted salt marsh sites (Grant Report Volume 2).

Coastal salt marsh wetlands are unique, valuable and highly productive ecosystems that provide vital habitat and refuge for fish, shellfish, and wildlife and perform important physical and chemical functions such as shoreline stabilization, sediment trapping, organic production and export, flood attenuation, and water quality maintenance. Urban development, agriculture, water-control actions and other legacies of human activities in coastal areas have resulted in the direct loss and alteration of a significant portion of this Nation's salt marsh wetlands. Loss estimates from the mid 1950s to the mid 1970s are as much as 400,000 acres (Tiner, 1984). While the direct destruction of salt marshes has been dramatically curtailed with regulatory protection, adverse effects from indirect sources such as nonpoint source pollution (including onsite waste disposal and stormwater runoff), oil and other toxic spills, and subsurface water withdrawal continue to degrade these unique systems (Kennish, 2001). Ecological criteria are needed to assess the condition of protected and restored coastal wetlands and their capability to provide aquatic life use support and other designated uses.

With the 1972 passage of the Clean Water Act, Congress mandated that states report on the condition of their waters and wetlands every two years for the National Water Quality Inventory Report. In the 2000 report, the US EPA summarized on the status of wetlands in the United States:

> *In their 2000 reports, only nine states and tribes reported the designated use support status for some of their wetlands. EPA cannot draw national conclusions about…conditions in all wetlands because the states used different methodologies to survey only 8% of the total wetlands in the nation. Additionally, only one state used random sampling techniques and two used a targeted approach (monitoring where problems were known or suspected).*

Clearly, there is a distinct lack of information currently available or being generated to assess the quality and condition of wetlands across the Nation. This issue will gain more attention, though, as States develop their Comprehensive Monitoring Program Strategy plans by 2004 as a contingent for their CWA §106(e)(1) funding. The recent US EPA guidance to states for the development of these plans, *Elements of a State Water Monitoring and Assessment Program (August 2002)*, cite wetlands as core indicators in a state plan.

To date, there has been little systematic effort to measure, document, and describe the condition of wetlands — both coastal and inland. Work by the USFWS National Wetland Inventory has enabled Federal and State governments to report on the status and trends of wetland acreage in some regions of the United States (Dahl, 2000). There have also been some isolated efforts to document wetland losses and changes in condition, largely through the analysis of historical and current maps and aerial photographs.

Much of the bio-assessment work in the United States has been associated with the development of biological water quality criteria for streams, rivers, and lakes (Gibson et al., 2000; Plafkin et al., 1989). In the last 10 years there has been significant effort focused on wetlands (US EPA, 2002; US EPA 1996; Brinson, 1993). Of particular note in this area is the work of the National Wetland Monitoring and Assessment Work Group administered by the U.S. Environmental Protection Agency (US EPA). Through technical and programmatic support, the Work Group helps states and tribes build their capacity to implement and sustain wetland monitoring and assessment programs that support wetland restoration and protection.

The goal of wetland biological assessment (bio-assessment) is to evaluate a wetland's ability to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable with that of minimally disturbed wetlands within a region. Although there has been abundant research and published literature on various aspects of salt marsh ecology (Bertness, 1999; Bertness and Ellison, 1987; Nixon, 1982; Whitlatch, 1982), the use of bio-assessment frameworks in salt marshes are still in the design and protocol development.

In the past four years, the review, evaluation, and discussion of standardized salt marsh survey protocols has been an area of focus for two regional forums: the Global Programme of Action / Coalition (GPAC) for the Gulf of Maine, coordinated by the Wells National Estuarine Research Reserve and the Great Marsh Working Group, coordinated by Massachusetts Audubon Society. Through these forums there has been active interaction and debate among researchers and investigators from state and federal agencies, universities, and regional nonprofits as to the most appropriate techniques and methods for surveying or monitoring salt marsh endpoints. Regional standardized protocols (in the form of guidelines) for the identification and evaluation of tide-restricted salt marshes have been released by the GPAC group (Neckles and Dionne, 2000). Other examples of regional efforts to develop standardized protocol, include shallow water monitoring for nekton (Raposa and Roman, 2001), monitoring salt marsh plants (Roman et al. 2001), and guidance for volunteers to monitor various salt marsh end points (Carlisle et al., 2002).

MA-CZM has been actively engaged in the development of wetland condition indicators since 1996, including four applied research projects, wetland mapping projects, and ongoing volunteer training and education. MA-CZM is an active member of both the

National Wetlands Monitoring and Assessment Workgroup and the New England Biological Assessment of Wetlands Workgroup.

The primary goal of the Cape Cod Salt Marsh Assessment Project was to advance and improve the salt marsh assessment approach and indicators developed by CZM in previous projects through its application to two separate investigations.

The first investigation, conducted in the 1999 field season (May to October index period), examined salt marsh indicators from six sites on the Cape Cod Bay coast; these sites had varying types and intensities of human land use or disturbance. Volume 1 reports on the first investigation.

The second investigation is a long-term comparison of indicators from selected tide restricted and reference salt marshes. The intent of this work is to document differences in indicators between the two groups of salt marshes and to examine response to tidal restoration actions. Volume 2 of the final report covers the second investigation.

Through the implementation of these two investigations, additional objectives will be realized. The collection and compilation of data on the condition of relatively undisturbed salt marshes is of critical importance to the evaluation and determination of impaired sites. This project will serve to expand the salt marsh reference site database. Another important aspect of this project will be to further examine the suite of indicators used for biological comparison and to explore new ones, based on the project data and literature/information base. The long term tide restriction study will provide insight on the utility of this assessment approach as a tool for tracking salt marsh restoration progress and trajectory.

Investigation 1: Salt marsh condition relationship to surrounding land use

The first phase, or investigation, of the Cape Cod Salt Marsh Assessment Project was focused on transferring the multi-metric assessment approach developed in the Waquoit Bay and North Shore pilot projects to a series of salt marsh sites on Cape Cod. Through this approach, indicators from salt marsh study sites are compared to regional reference sites. The working hypothesis, based on results from the previous project applications, is that as human disturbance increases, ecological integrity—as represented by biotic metrics and indices—will decrease.

Study Design and Sites

The land use investigation study design approach was based on a comparative framework where minimally-disturbed wetlands—or reference sites—provide the basis for examining other wetlands—or study sites—which are adversely affected by human land use stressors. The design includes study sites with varying levels of surrounding land use (stressors) to examine ecological responses along a gradient of impact. All of the sites for this investigation were located on estuaries connected to Cape Cod Bay (north side of Cape Cod) with similar tidal hydrology. Descriptions of the study sites below explain each site's landscape setting and other important features.

For each site we compared three measures of land use or human disturbance, including: modeled nitrogen and impervious area as well as a multi-indicator method called the Land Use Index. Nitrogen is the principle driver of coastal eutrophication and anthropogenic sources are responsible for reduced water quality and degraded aquatic habitat (McClelland et al.). Impervious area is widely used as surrogate for urbanization and watershed-based work has established direct association between increased impervious area and decreased ecological condition in streams and rivers (Schueler, 1994; Center for Watershed Protection, 1998). The Land Use Index is a method MA-CZM developed to integrate a number of different land uses and stressors into a single quantifiable score. The Land Use Index combines Geographic Information System (GIS) data on wetland extent, land use classification, and impervious area to produce a ranking of a site's exposure to human disturbance. The Land Use Index methodology is described below.

Biological, chemical, and physical data collected at wetland study sites are compared to data collected at the wetland reference sites. Multi-metric data analysis techniques are employed to examine attributes and variables of biological data and these metrics are combined into a quantitative index. A metric is a parameter or variable that represents some feature, status, or attribute of biotic assemblage, chemical state, or physical condition. In a multi-metric approach, several different metrics are chosen in order to effectively capture and integrate information from individual, population, guild, community, and ecosystem levels and processes. Metrics are selected based on literature reviews, historical data, and professional knowledge. The quantitative output from each metric is then combined to produce an overall index which serves to summarize the biological condition.

Field work for this investigation was conducted from May to October 1999 at six salt marsh sites (Figure 1). The biotic assemblages sampled were plants (macrophytes) and aquatic macroinvertebrates. Nutrient concentrations were also measured (nitrogen suite and phosphorous).

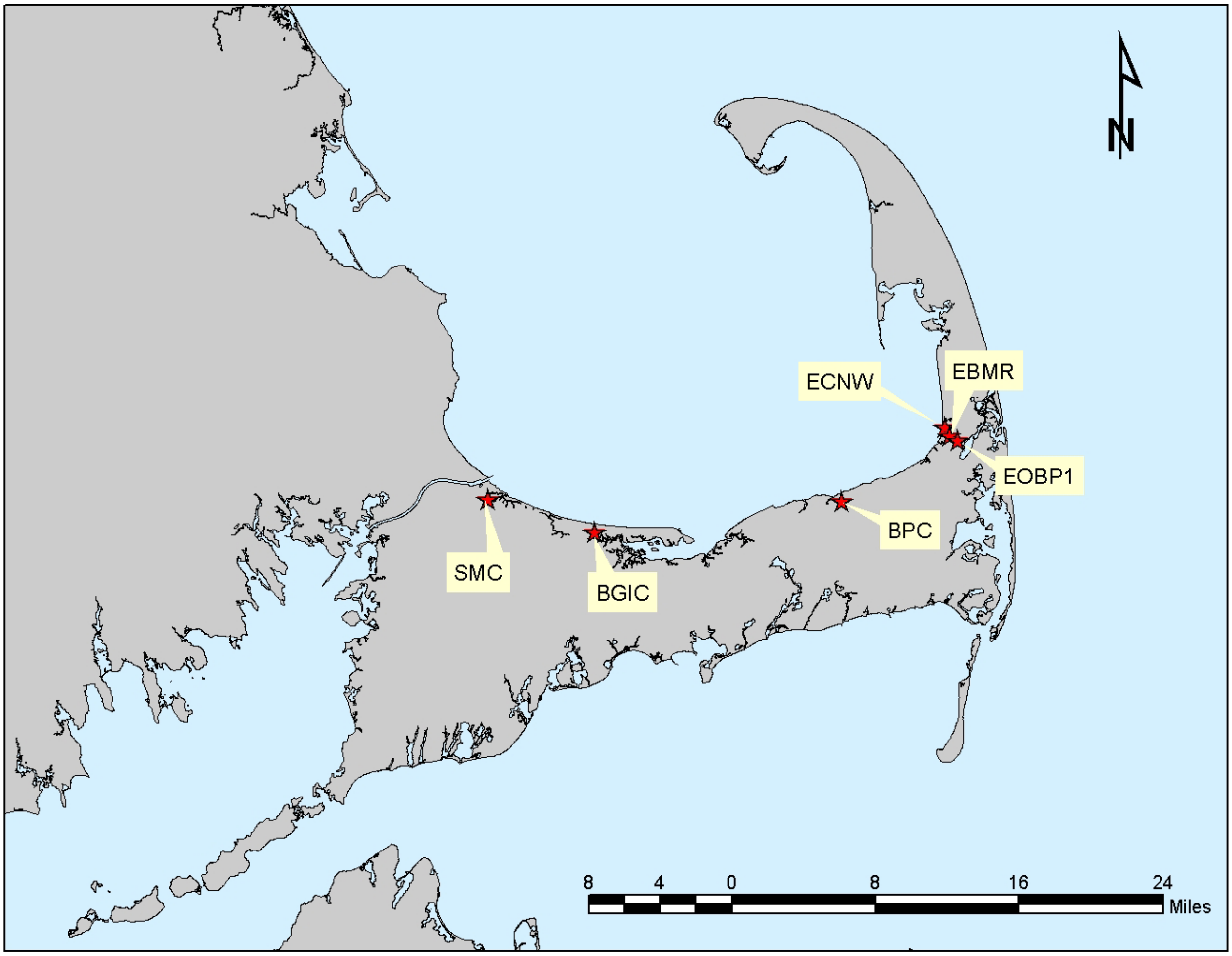

Figure 1. Locus map showing salt marsh sites for Land Use Investigation.

Four study sites and two reference sites were selected for this investigation. All sites are located on the Cape Cod Bay coast, distributed from the west in the town of Sandwich to the east in the town of Eastham. A description of each site, its characteristics and landscape setting follows. Within each marsh, a distinct evaluation area was delineated according to the protocol described below in Methods.

BGIC

Barnstable Great Island Creek (BGIC) was one of two reference sites selected for this investigation (Figure 2). This site is located within the extensive Great Marshes complex behind the Sandy neck barrier beach in the town of Barnstable. Much of this salt marsh and barrier beach dune system is maintained as conservation land in perpetuity, owned by the Commonwealth of Massachusetts and managed by the town. There is little to no human presence or sources of disturbance in this area. Recreational walking trails are present to the north of the evaluation area and there is infrequent use of a off-road trail by town resource management vehicles. In addition, this salt marsh area is the site of ongoing research by other organizations. Linear grid ditches on the marsh are remnant physical and hydrologic alterations. No evidence of fill is present. The evaluation area of this site is 21,597 m^2.

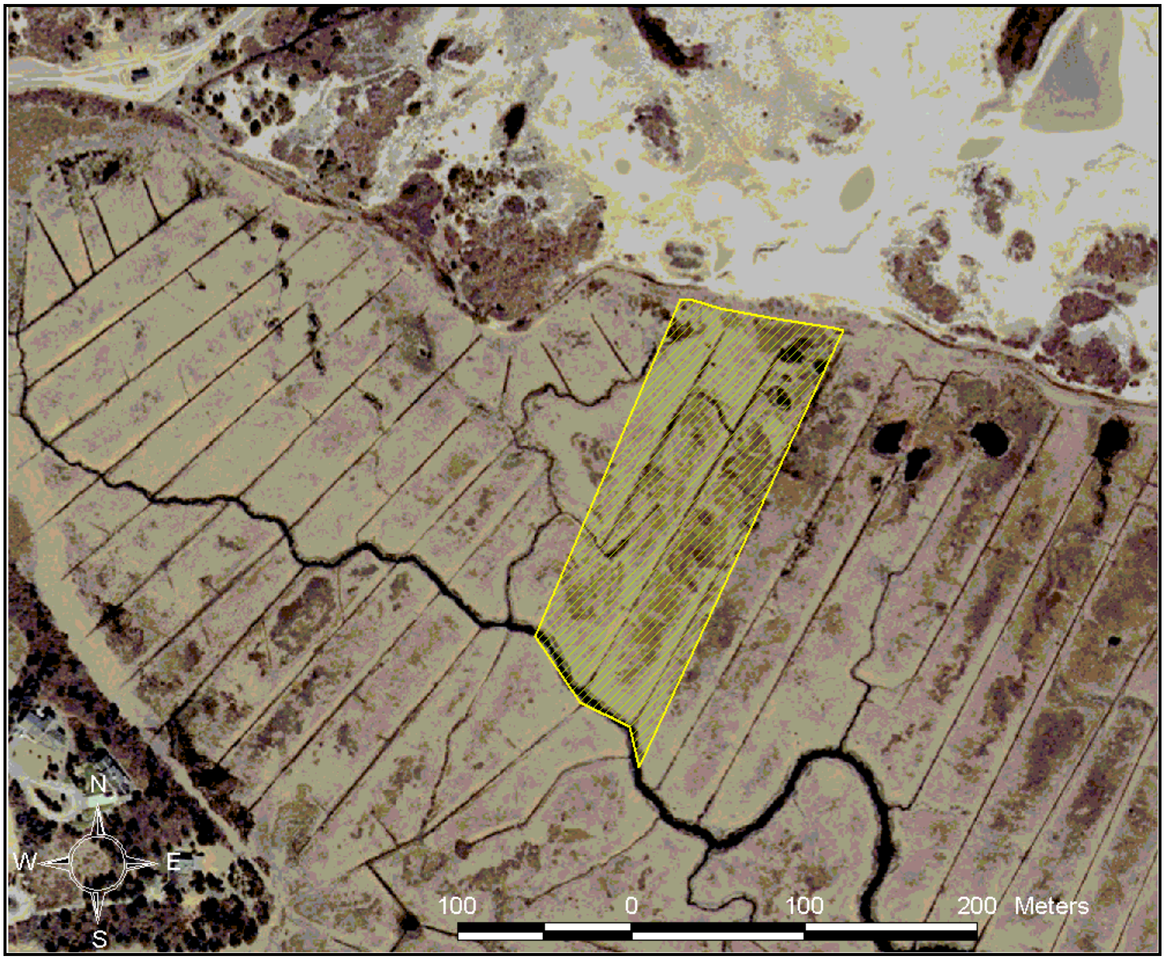

Figure 2. BGIC Reference site with evaluation area.

EBMR

Eastham Boat Meadow River (EBMR) represents the second reference site selected for this investigation (Figure 3). Located near the mouth of the creek at Cape Cod Bay, the site is held in conservation easement by The Nature Conservancy. The surrounding upland is privately owned and is characterized as sparse residential. Three single family houses are located on the upland neck, set well back from the salt marsh edge. Other than on-site septic systems, which are assumed to be adequately sited and functioning properly, there are no other notable sources of pollution of disturbance. Historical linear ditches are present but are not extensive. The evaluation area for this site is 11,340 m^2.

Figure 3. EBMR Reference site with evaluation area.

SMC

Sandwich Mill Creek (SMC) is the one of four study sites of the investigation (Figure 4). Located directly off of Route 6A in Sandwich, this salt marsh is surrounded on all sides by development—primarily commercial and residential. Mill Creek flows through bridges under the active railroad and Route 6A, though neither of these features are judged to present hydraulic tide restriction. Substantial fresh water flows out of Shawme Lake, a small impoundment, into Mill Creek. There are only a few linear ditches, but there appears to be substantial historical fill, especially along Route 6A. The evaluation area for SMC is 4,320 m^2.

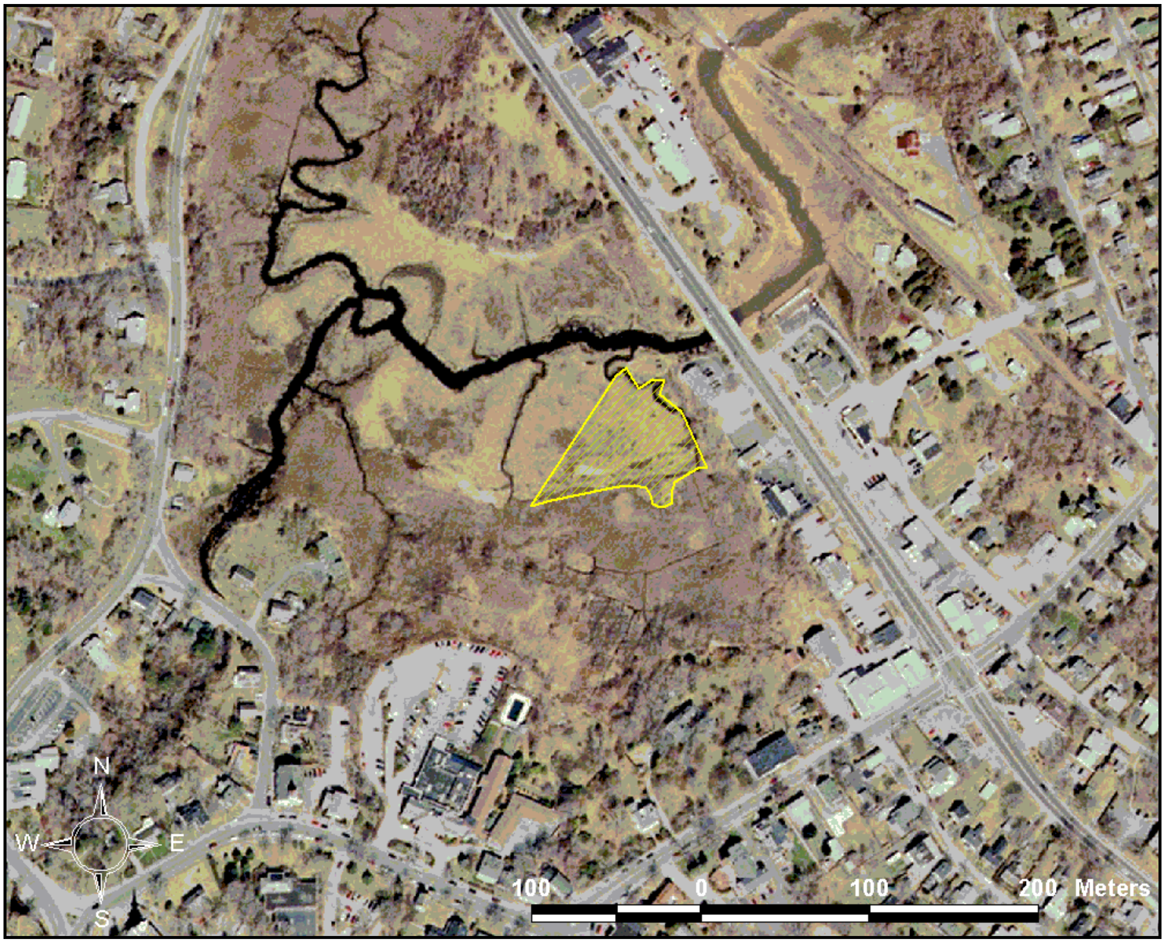

Figure 4. SMC Study site with evaluation area.

BPC

Brewster Paines Creek (BPC) study site also directly abuts Route 6A (Figure 5). The evaluation area of this site was located on the north side of the road, on the marine side (below) of what appears to be a undersized culvert acting as a hydraulic tide restriction. Commercial, residential, and agricultural (small horse farm) land uses surround this site. The Route 6A embankment represents a significant amount of historical fill, effectively bisecting the marsh into two separate units. In addition, the embankment has been armored with rip-rap, providing no habitat or vegetated buffer capacity. A stormwater outfall discharges runoff from the commercial development catchment directly to the evaluation area. There are a few historical ditches on this marsh. BPC's evaluation area is 5,708 m^2.

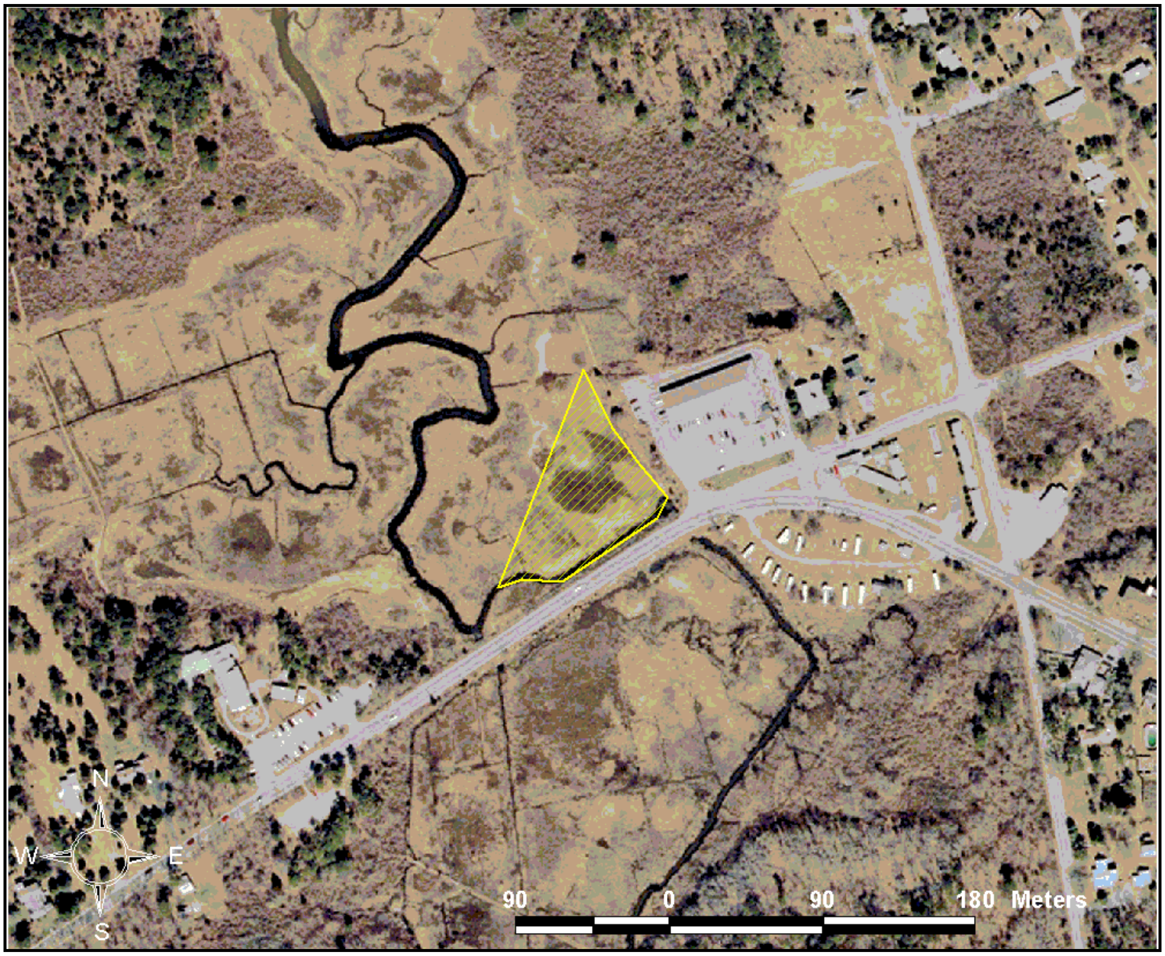

Figure 5. BPC with evaluation area.

ECNW

Eastham Charles Noble Way (ECNW) is located just above Bridge Road and is part of the large salt marsh complex associated with Boat Meadow River (Figure 6). The study site is a pocket marsh, surrounded on three sides by residential development. There appears to be evidence of some historical fill along the edges as well as significant linear grid ditches. The evaluation area is 2,616 m^2.

Figure 6. ECNW with evaluation area.

EOBP

This study site is located at the upper reaches of Boat Meadow River on the marine side of the Cape Cod Rail Trail (bike path). Eastham/Orleans Bike Path (EOBP) site is a pocket marsh that may have been formerly cut off from tidal hydrology at the neck on the north side. 1970's state Wetland Conservancy maps show this site as having brackish or fresh marsh vegetation. Presently there is no tide restriction affecting this site, though the culvert under the bike path is a tide restriction for the salt marsh site just to the south. Residential land use dominates the eastern side of this marsh and stormwater from the Route 6 and its rotary interchange enter the restricted marsh on the south and then flows under the culvert on ongoing tide to this site. Historical fill and ditching is present. The evaluation area is 4,902 m^2.

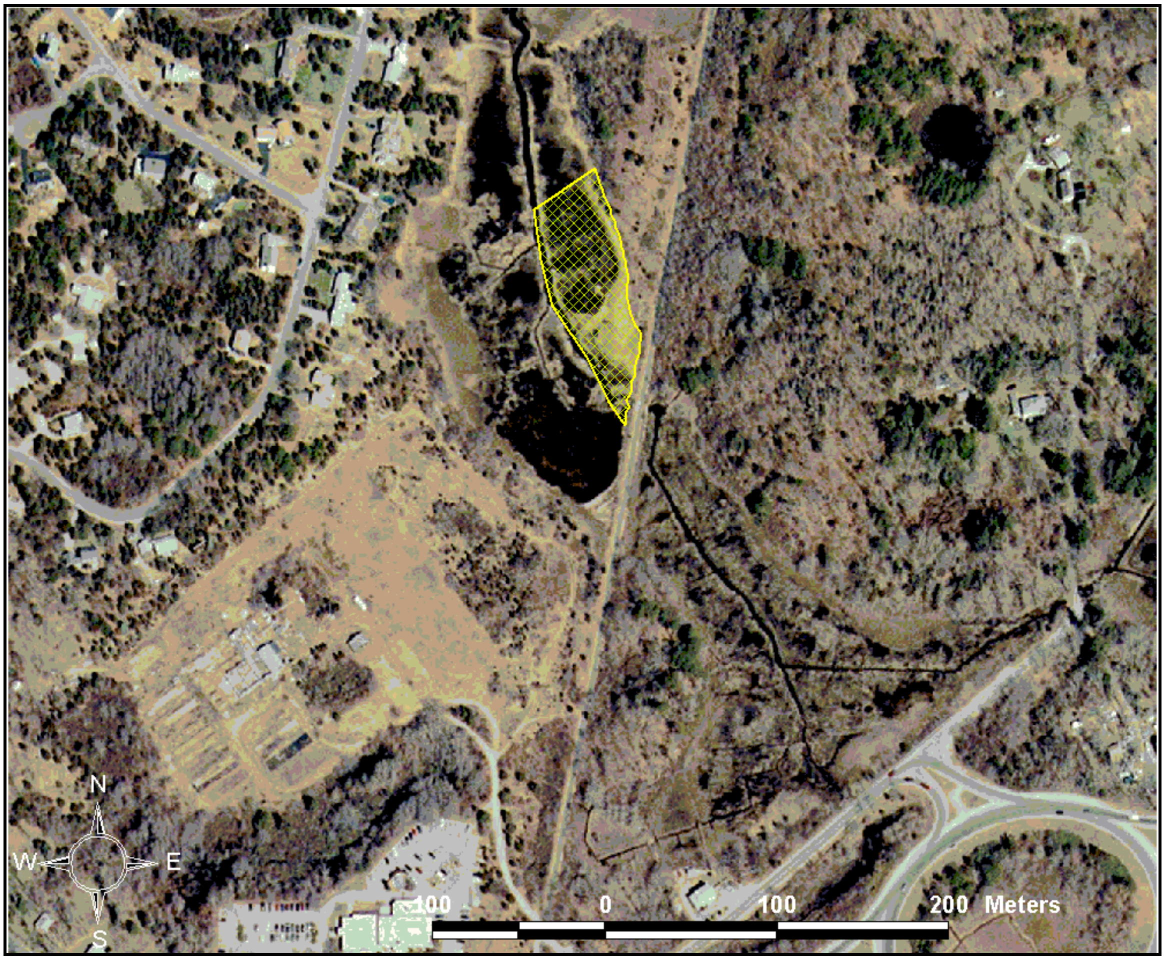

Figure 7. EOBP with evaluation area.

Methods

Evaluation Area

For this investigation, a specific evaluation area was established within the salt marsh study sites. The decision to designate an evaluation area was driven by several factors. The first was a desire to reduce natural variability caused by size, since salt marsh sizes can range from less than one to well over thousands of acres. Another reason was to be able to focus more specifically on the areas of a site that are closer to potential sources of stress and therefore more prone to exhibit degradation. The last reason was logistical, allowing for manageable study site sizes.

The evaluation area for all salt marsh sites in this investigation (both reference and study sites) was established by including all of the habitat (marsh surface, sub- or intertidal creeks and channels, pools and pannes) in an area created by a bisecting transect located at a point 92 meters (300 feet) from designated start point (Figure 8).

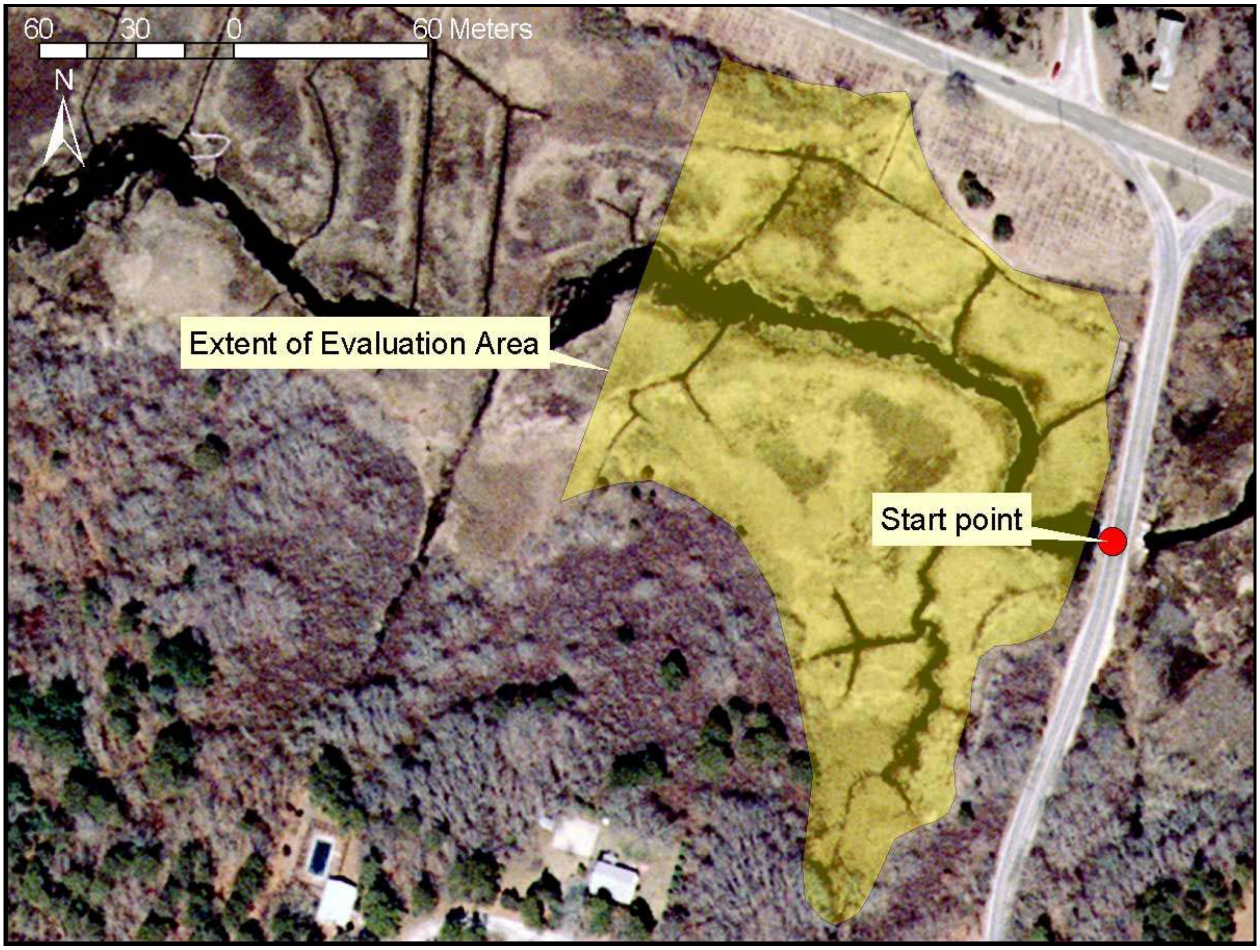

Figure 8. Salt marsh site evaluation area.

Disturbance Indicators

Wetlands are typically located in low-lying areas of the landscape, causing them to act as receiving points for upland sources of sediment, nutrient, and other pollutants (Nixon, 1986). Although some aquatic resources, such as some types of wetlands, are able to perform water quality-related functions, including sediment trapping and nutrient uptake or transformation, pollutant loads entering these resources may actually exceed their capacity to store, absorb, or transform them (Whigham, et al., 1988). In addition, these pollutants may have adverse effects on other aquatic resource functions and conditions such as flood storage and desynchronization, wildlife habitat and vegetation, production export, recreation, and successional state (National Research Council, 1991).

As the type and intensity of proximate human land uses increases, the wetland area becomes subject to corresponding changes in its hydrology, nutrient and sediment regimes, and habitat quality. For this investigation, three indicators of disturbance were utilized for a standard set of land use classes in the 100 meter buffer zone surrounding the study site. Massachusetts uses the MacConnell Land Use Classification with 21 sets of land uses types.

The first disturbance to be examined was impervious area. Impervious cover has been shown to strongly influence the quality of receiving waters and the health of aquatic habitat (Schueler, 1994; Center for Watershed Protection, 1998). Impervious surfaces, such as roads, driveways, rooftops, and other features of developed landscapes, impact water quality by altering the natural hydrology of surface and groundwater, collecting atmospheric and transportation-related pollutants, limiting the adsorption and uptake of nutrients and bacteria by soils, and increasing the temperature of surface waters (Schueler, 1994). The Center for Watershed Protection (CWP) has demonstrated that significant water quality impacts can result from as little as 10 percent coverage of a watershed by impervious surfaces (CWP, 1998).

MA-CZM and the US Fish and Wildlife Service (USFWS) developed a set of impervious area coefficients as part of a nonpoint source pollution assessment of the Parker Watershed (Baker and Carlisle, 2003). These coefficients are listed in Appendix A. The total area of impervious area in the 100m buffer was estimated by applying these coefficients to the MacConnell land use classes for each site.

The second disturbance indicator examined was anthropogenic nitrogen. Nitrogen is generally the limiting nutrient for New England marine and coastal waters. Human sources of nitrogen accelerate eutrophication and result in chronic periods of low dissolved oxygen, excessive and unsightly algal blooms, shifts in aquatic plant community dynamics and colonization by invasive species.

The Buzzards Bay Project has developed a set of anthropogenic nitrogen coefficients for the MacConnell Land use classes as part of their ongoing work to determine loadings to coastal embayments (Costa et al.; http://www.buzzardsbay.org/bbpnitro .htm). These coefficients are listed in Appendix A. The load of nitrogen to the study site from land use in the

100m buffer was estimated by applying these coefficients to the MacConnell land use classes.

A Land Use Index (LUI) was the last disturbance indicator to be examined. It was created in an attempt to quantify cumulative human disturbance to a wetland study site. The LUI coefficients for each MacConnell land use type are based on four sets of numbers: nitrogen, phosphorous, and suspended solid loadings, and average amount of impervious area. The LUI coefficients are listed in Appendix A.

The LUI score for each site was computed by combining the output of a Geographic Information System (GIS) analysis with the results of a on-site rapid assessment worksheet (Appendix B). The steps taken to compute the LUI are:

- Delineate the wetland study site and specific evaluation area;
- Isolate and classify surrounding land uses;
- Establish the 100m buffer zone (zone of influence);
- Compute areas of distinct land uses within zone of influence;
- Apply land use coefficients (see Appendix A);
- Complete on-site rapid assessment worksheets (see Appendix B);
- Total (average) results to generate the Land Use Index.

The LUI scores are structured to indicate the relative amount and intensity of human disturbance around a given site. The Land Use Index scale is 1-100, with the lower scores indicating greater human disturbance.

The scores for each disturbance indicator are presented in the Results section.

Plants

At each salt marsh site, salt marsh vegetation was surveyed along six transects. The location of the transects were determined according to the following protocol. The evaluation area was segmented into three sections, located at 100 foot intervals along the primary transect (Figure 9).

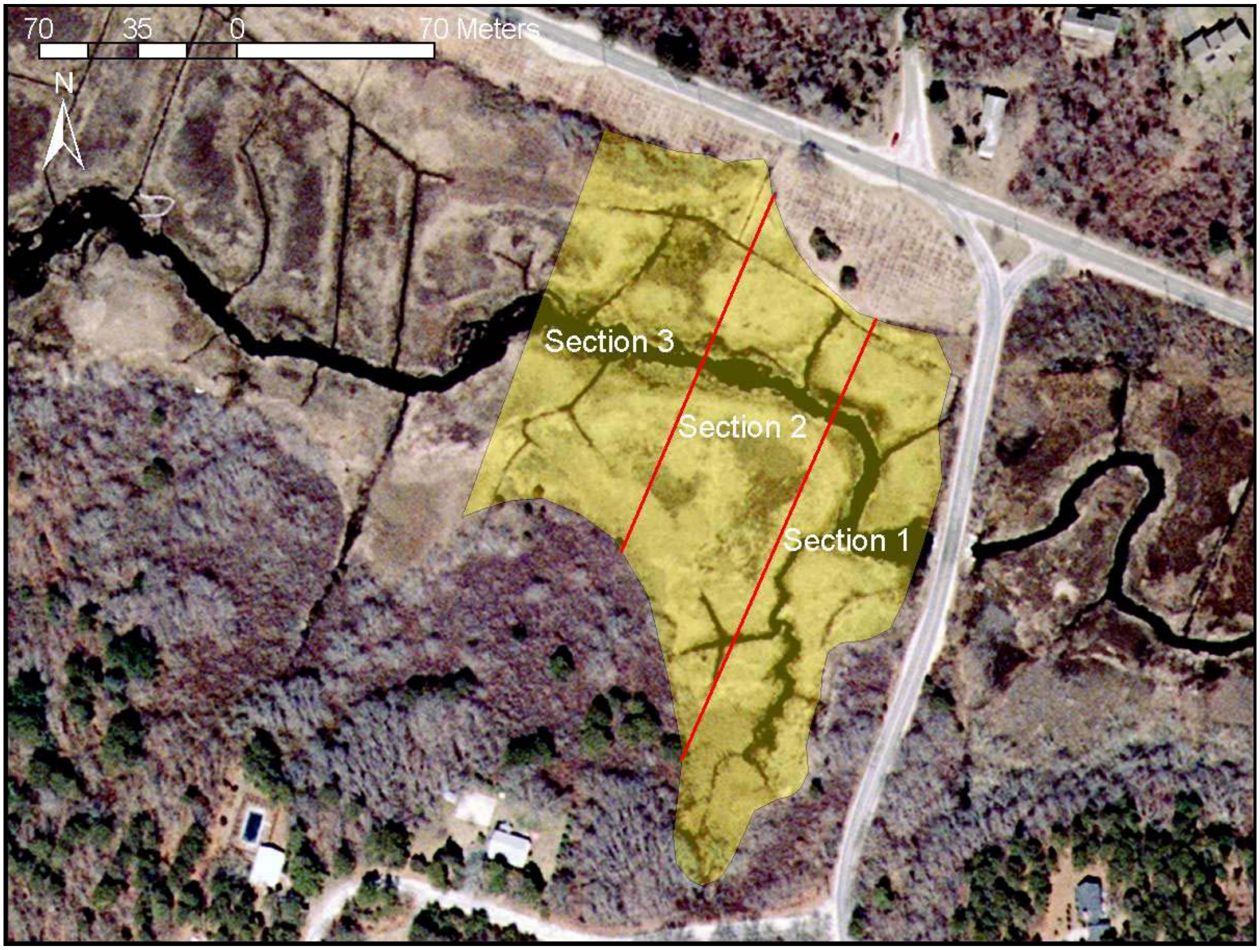

Figure 9. Sections of the evaluation area for plant survey.

In each of the sections, two transects were placed. The transect locations were determined by generating a random integer between 0 and 100 according to a calculator algorithm. The random integer was the distance in feet along the primary transect from the start of each section. If the location of a transect placed it on a ditch or channel or within 3 feet of another transect, that number was rejected, and a new number/location was randomly generated.

The transects were oriented to run from the bank (primary transect) to the upland edge, according to a consistent compass bearing (for all six transects at the study site). A stake was secured in the substrate at each end of the transect and labeled with the site and transect code.

Along each transect, 1m^2 plots were placed every 60 feet, starting at the creek edge progressing along the entire length of the transect up to the upland edge. The last plot was always located at the salt marsh border regardless of whether the 60 foot interval occurred there.

In each plot, every plant was identified to genus and species. For each unique species within the plot, the abundance was determined by comparing the visual estimates of two investigators and then applying a standard cover class value for nine coverage ranges. The standard cover class categories are contained in Appendix B. The community type (low marsh, high marsh, or fringe) for each plot was recorded. Coverage estimates included areas within the 1m^2 plot that were not occupied by living, rooted plants (including wrack, inorganic matter, bare ground, and open water) which were recorded as “other”.

Plant surveys were conducted during peak maturity and biomass in August and September.

Aquatic Macro-Invertebrates

The sampling protocol was designed to survey representative populations of macro-invertebrates from the sub- or inter-tidal open water feature (channel, bay, pond) and the inter-tidal salt marsh bank (generally characterized by the tall form *Spartina alterniflora*).

Within the salt marsh Evaluation Area, sampling stations are located along the primary transect or spine at the following three intervals from the starting point: 0 to 20 feet, 140 to 160 feet, and 280 to 300 feet (Figure 10).

At each of the three invertebrate stations, the following discrete samples were collected at low tide (within 90 minutes on either side of the actual time of low tide):

- Sub- or inter-tidal open water zone:
  - ✓ one D-Net sweep along the bottom substrate, edge of bank toe, and next to any large debris (logs, rocks, tires),
  - ✓ one auger sample from top of substrate to a depth of approximately 6 inches (15-16 cm), and
  - ✓ one 18” x 18” survey plot on the surface of the benthic substrate.
- Inter-tidal bank zone:
  - ✓ one 18” x 18” survey plot on bank surface.

Each sample was placed in a sealed plastic bag, and labeled with the following: site number, site name, date of sampling, sample number, sampling method, name of sampler. After sorting the discrete samples for each station are combined to form a composite sample of the various habitats sampled.

The site field data sheets recorded the relevant sample numbers. All samples were bagged, preserved in 90% ethyl alcohol, placed in a cooler and returned to the laboratory for sorting, identification and enumeration.

At each site, a habitat characterization is completed that summarizes the salt marsh conditions at the sampling site. The information collected includes the characterization of hydrology, vegetation, substrate, available food sources for invertebrates, and visible evidence of human disturbance for the site.

Temperature, salinity, dissolved oxygen and pH were also measured at each station prior to sampling with a YSI 600 probe attached to a YSI 650 hand-held data logger. Water depth was shallow, so stratification was not an issue in most cases and bottom measurement were collected. In instances when wide variability between surface and bottom measures were observed, both surface and bottom measures were recorded.

In the laboratory samples were sorted, separating organisms from debris. Invertebrates were then placed in glass vials in 90% ethyl alcohol and sealed with screw tops. Invertebrates were later counted and identified without sub-sampling to Family Level (Fauchald, 1977; Gosner, 1978; Meinkoth, 1988; Pollock, 1998, Weiss, 1995). Processed samples were returned to their labeled vials with 90% ethyl alcohol for archival storage. A sample custody sheet recorded full details of all samples, and the stage of their progress from marsh to archival action.

The first invertebrate survey was conducted the week May 24 to 28, 1999 and the second was during the week of August 23 to 27, 1999.

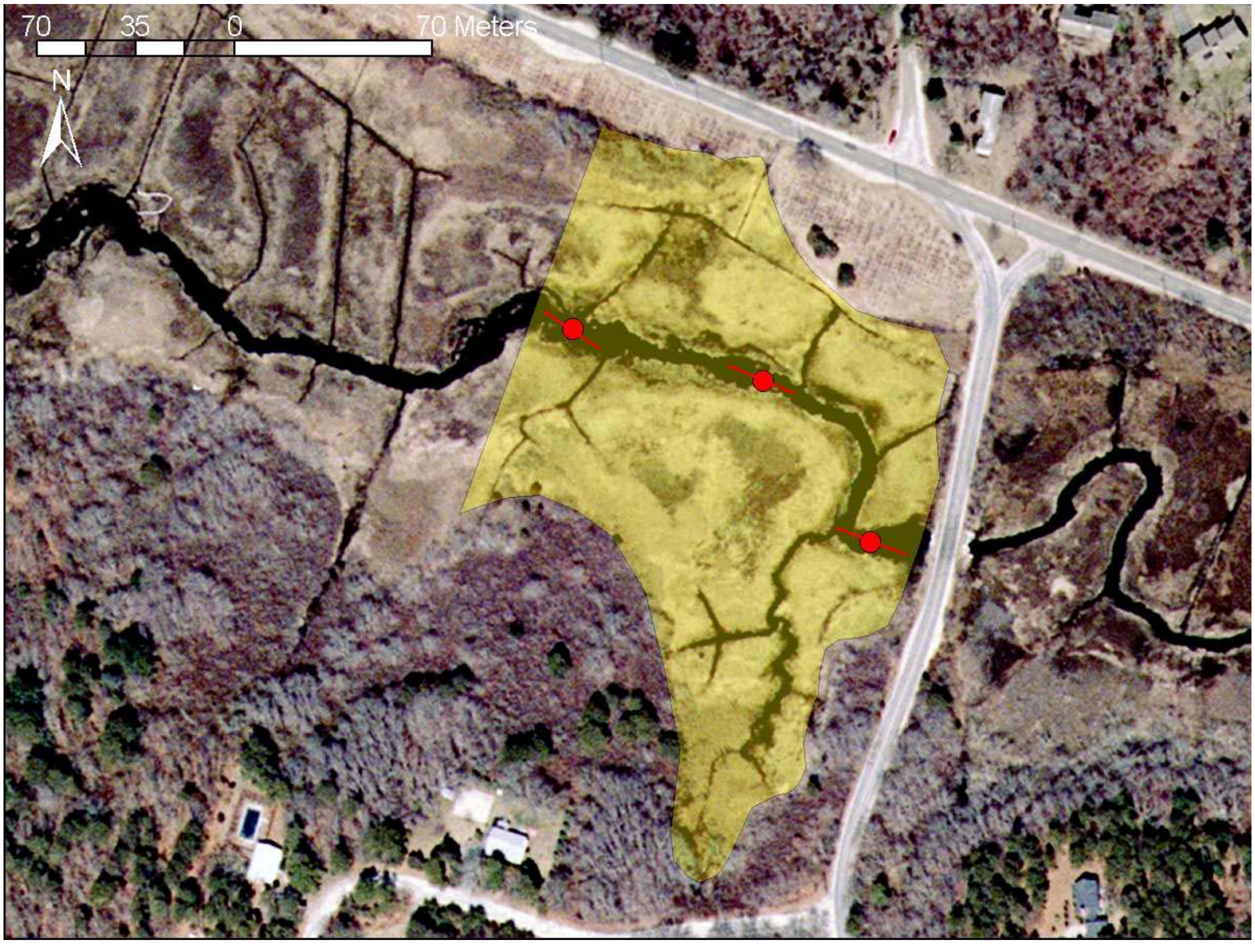

Figure 10. Stations for invert samples.

Results and Discussion

Impervious Area

The application of the impervious area coefficients as described above, resulted in scores ranging from a low of 3.29% of the 100m buffer (BGIC-ref) to 20.6 % of the 100m buffer (ECNW). The mean was 13.08 and the standard deviation was 6.37.

Table 1. Estimated Impervious Area for six salt marsh sites in percent of 100m buffer.

	BGIC-ref	EBMC-ref	ECNW	EOBP1	SMC	BPC
% Impervious Area	3.29	11.42	20.60	9.06	17.07	17.06

Nitrogen Loading

The application of the anthropogenic nitrogen loading coefficients as described above, resulted in scores ranging from a low of 0 kg/year (BGIC-ref) to a high of 102.34 kg/year (BPC). The mean was 38.86 and the standard deviation was 41.61.

Table 2. Estimated nitrogen load to six salt marsh sites in kilogram per year.

	BGIC-ref	EBMC-ref	ECNW	EOBP1	SMC	BPC
Nitrogen (kg/yr)	0.00	16.46	23.20	11.81	79.31	102.34

Land Use Index

The application of the LUI methodology as described above, resulted in scores ranging from a low of 30.78 (BPC) to a high of 91.65 (BGIC-ref). The mean was 61.74 and the standard deviation was 22.61.

Table 3. Land Use Index scores for six salt marsh sites.

	BGIC-ref	EBMC-ref	ECNW	EOBP1	SMC	BPC
LUI-GIS	99.00	75.35	65.67	84.19	47.93	28.70
Rapid Assessment	84.29	80.00	60.00	48.57	34.29	32.86
LUI-FINAL	91.65	77.68	62.84	66.38	41.11	30.78

Plants

A total of twenty-seven species were surveyed and identified at the six salt marsh sites. The mean number of species (taxa richness) was 11.83, the minimum was seven (EOBP), and the maximum was sixteen (BGIC). The species with the highest frequency of occurrence was *Spartina alterniflora*, occurring in 150 plots; next highest frequency was *Spartina patens* (freq. = 140). Eight of the twenty-seven species were found only at one site and of these eight, two occurred in only one plot (freq. = 1). The average number of 1m^2 plots per site was 35.

Table 4. Metrics and rational for salt marsh Plant Community Index.

Metric	Rational	Response
Community Similarity	Community composition will change with disturbance, with perennial grass species abundance ratios shifting and loss of diverse forbs.	Decline
Taxa Richness	Eutrophication, tide restriction, and other stressors will decrease number of species, as above.	Decline
Invasive Species	Disturbance will favor conditions for competitive advantage to invasive species.	Rise
Nutrient Affinity	Eutrophication will allow for increase of species with competitive traits to utilize nutrient surplus.	Rise
Salinity Tolerance	Tide restriction or shifts in local hydrology reduce salinity and provide conditions for brackish species.	Decline
Persistent Standing Litter	Plants with standing litter in the winter have tough cellulose structure in stems and does not serve as valuable food source for herbivores or detritivores.	Rise
Opportunistic Species	Disturbance will favor conditions for competitive advantage to opportunistic species.	Rise
Habitat Affinity	Habitat specialists (e.g. high marsh forbs) will decline with degradation.	Decline

The metrics used for the Plant Community Index (PCI) are listed and described in Table 4. The method for scoring the metrics was based on the following procedure. First, target reference values for each metric are obtained by averaging the results from the two reference sites. For each metric, scoring criteria are established by examining the data means, standard deviations, quartiles, and reference values. The plant attributes, index metric scores, and the scoring criteria are contained in the Appendix C. The results of the multi-metric PCI analysis are displayed in Table 5 and graphically in Figure 11.

The PCI scores ranged from 100 (EBMR-ref) to 33 (BPC). The median score was 72. Reference site BGIC-ref received a PCI of 96, with the large abundance of the dense turf grasses (high marsh S. patens) slightly affecting the persistent standing litter metric score. Sites BPC, SMC, and EOBP1 are considered to be exhibiting signs of plant community impairment.

Table 5. Plant Community Index scores.

Site	IVI Score
BGIC-Ref	95.83
EMBR-Ref	100.00
ECNW	87.50
BPC	33.33
SMC	58.33
EOBP1	58.33

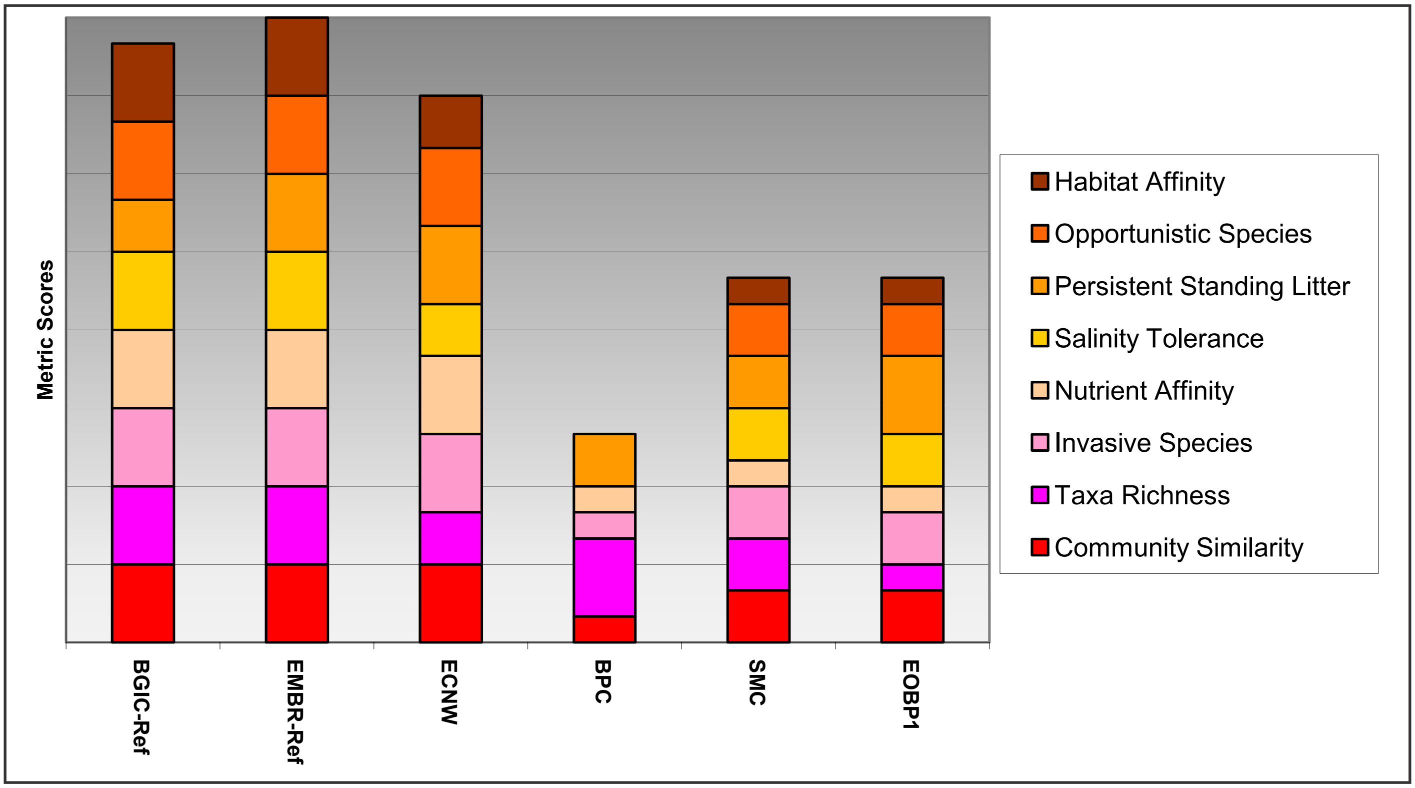

Figure 11. Plant Community Index metric scores.

Aquatic Macro-Invertebrates

Thirty seven families (or taxonomic groups) were represented throughout the sites sampled. The most commonly occurring families were *Gammaridae* (Amphipoda), *Palaemonidae* (Shrimp), *Leptochellida* (Tanaidacea) and *Sphaeromatidae* (Isopoda). The numbers within each family/group varied between seasons, with 932 organisms in the May survey and 2361 in August. A number of families sampled in May were not observed in August, and vice versa; however, the taxa richness was greater in August for all sites but one (that remained the same). The size of individuals was generally larger in August than in May, facilitating identification at that season.

The invertebrate samples for May and August were processed and enumerated separately. The data was then combined by averaging the seasonal values for each site. The method for analyzing and scoring the metrics was similar to that for the PCI. The metrics used for the Invertebrate Community Index are listed and described in Table 6. The invertebrate metric scores and scoring criteria are contained in Appendix D.

Table 6. Metrics and rational for salt marsh Invertebrate Community Index.

Metric	Rational	Response
Total Taxa Richness	Some disturbance can increase habitat opportunity, and the number of taxa may rise, but the intensity of disturbance increases habitats are destroyed and taxa drop out of the community.	Decline
% Predators	Predators are at the top of the food chain and are susceptible to bioaccumulation of pollutants and other environmental problems that may impact the organisms upon which they rely for food.	Decline
% Representation of Dominant Taxa Group	Balanced community will have composition among taxa, with three or more dominant groups. Increasing disturbance usually favors the most resilient taxa.	Rise
% Representation of Dominant Trophic Group	Detritivores always dominate salt marsh invertebrate communities, but as disturbance increases, more detritus is added to the system, and this trophic group may burgeon.	Rise
% Abundant	With increasing disturbance, robust organisms are inclined to outcompete sensitive taxa, and as a result the % of abundant, more tolerant, species rises.	Rise
% Rare	As habitat niches diminish, sensitive organisms with naturally low populations are removed from the community.	Fall
% Palaemonidae Shrimp	Palaemonidae shrimp respond positively to detritus enrichment from eutrophication.	Rise
% Introduced Species	Introduced species such as Littorina littorea and Carcinus maenas are hardy, competitive, and invasive.	Rise
Community Taxa Similarity Index	Resemblance of communities to reference condition will diminish as stressors increase.	Decline
Community Trophic Similarity Index	Resemblance of trophic patterns to reference condition will diminish as stressors increase.	Decline

The results of the multi-metric ICI analysis are displayed in Table 7 and graphically in Figure 12. It is interesting to note several observations. Firstly, the reference sites, BGIC and EBMR, do not score 100. While the reference value was derived from their combined values, the scoring criteria are established within the context of the data from all of the surveyed sites. For each reference site, certain invertebrate community attributes deviated substantially from the target values. For example, reference site EBMR had lower average taxa richness from May and August than other sites. Reference site BGIC had two metrics, Dominant Taxa Group and Dominant Trophic Group, which were highly influenced in May by samples which were heavily dominated by amphipods and August's by relatively large numbers of tanids. The reference sites scores though—80 (BGIC) and 87 (EBMR)—are values that align with what the investigators would consider to be high quality conditions. The metrics, Taxa Richness, Percent Rare, and Percent Introduced Species, all had the lowest variability, while Percent Predators and Percent Palaemonidae Shrimp had the largest differences in scores.

Table 7. 1999 Invertebrate Community Index Scores.

Site	ICI Score
BGIC-ref	80.00
EBMR-ref	86.67
SMC	63.33
BPC	66.67
ECNW	73.33
EOPB1	70.00

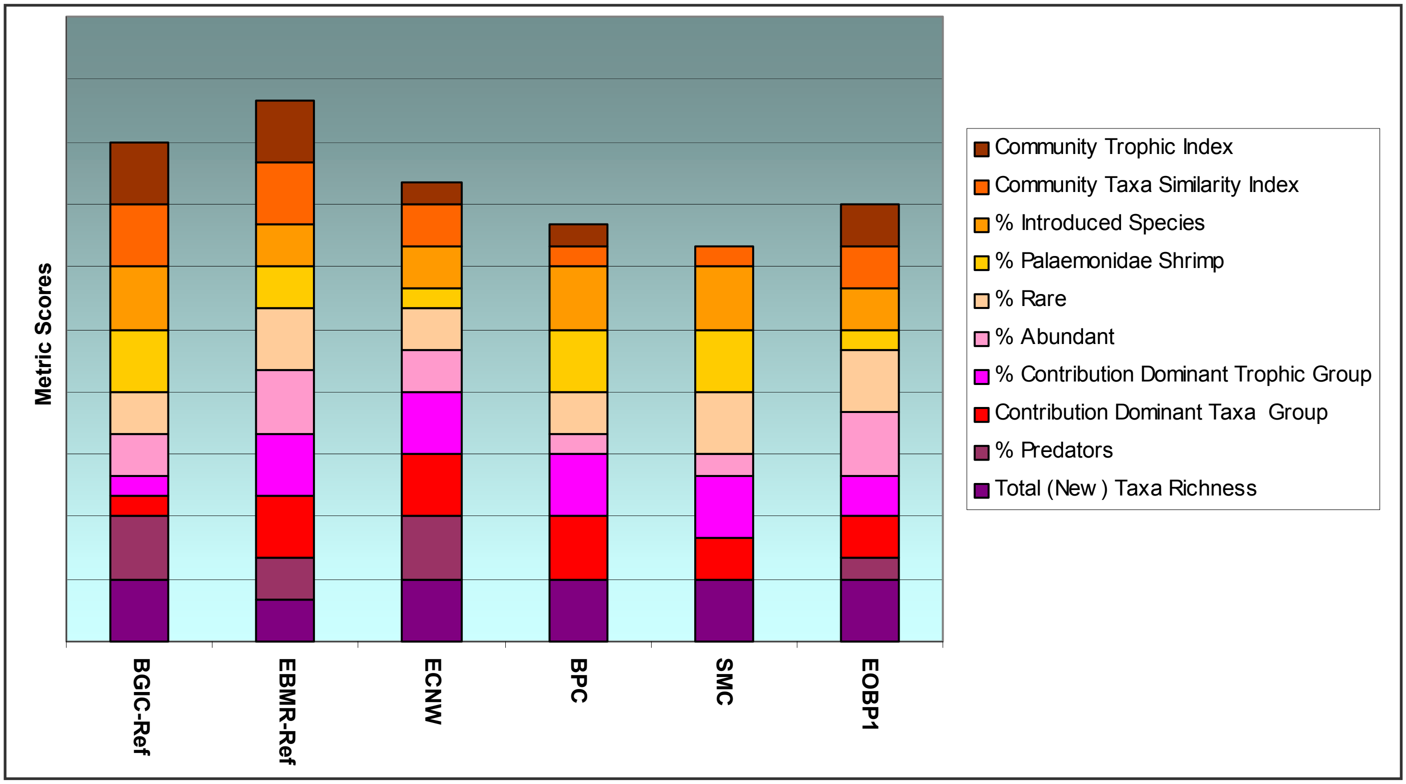

Figure 12. Invertebrate Metric Scores.

Cross-Indicator Comparison

From the data, a comparison was conducted of correlation coefficients to examine the relationship between the various indicators. In Table 8, the correlation coefficients for the disturbance indicators (Impervious Area, Nitrogen Loads, Land Use Index) and condition indicators (Plant Community Index, the Invertebrate Community Index and the Wetland Ecological Condition (WEC) [average of the PCI and ICI] are displayed in a matrix. As a rule of thumb, the correlation coefficients can be interpreted by their departure from a perfect relationship of 1.00. Guidelines suggest that coefficients from 0.71 to 0.99 show a strong relationship; a moderate relationship would be 0.31 to 0.70 and weak below 0.31. Within this framework, all of the relationships between the wetland indices are moderate or strong, with the majority being very strong (above 0.80). Of particular note is the strength of the Land Use Index to all other indicator scores. Also worth noting, is the relatively weak association of the Impervious Area indicator.

Table 8. Correlation coefficient matrix for investigation indicators.

	LUI-FINAL	%Imp	N (Kg/Yr)	PCI	ICI	WEC
LUI-FINAL	■					
%Imp	-0.74	■				
N (Kg/Yr)	-0.95	0.62	■			
PCI	0.81	-0.42	-0.66	■		
ICI	0.97	-0.71	-0.95	0.75	■	
WEC	0.92	-0.56	-0.81	0.97	0.89	■
▨	= Shading indicates strong correlation (> 0.70)					

Relationship of Disturbance to Condition Indicators

Another, more synoptic, view of this investigation's data, can be derived from the examination of the ability of the disturbance indicators to explain the biotic condition indicators. This type of regression analysis is one advocated by developers of biological indices (Karr 1999; EPA 2002) where the biological response (y-axis) is examined in the context of the human disturbance gradient (x-axis).

The following three figures depict the linear regression and R^2 values for the wetland condition scores and the human disturbance indicator scores for this Cape Cod investigation as well as values from an analogous study on the North Shore in 1998. Plant Community Index scores are represented by squares and the Invertebrate Community Index are shown as triangles. The data points from this investigation are depicted in color, while the North Shore points are in black.

The first disturbance indicator is modeled impervious areas, and its relationship to the two biotic condition indicators is weak (Figure 13). This finding raises questions as to the applicability of imperviousness as a useful indicator for wetland assessment work. Perhaps it is best suited to larger scale assessment, drainage area or sub-watershed and up. Future work will continue to examine impervious area as a disturbance indicator.

Nitrogen was the second disturbance indicator examined and the relationship here as indicated by the linear regression is fairly strong (Figure 14). The R^2 values are not particularly high, but for both the PCI and ICI they are significant at the 95% confidence level. This pattern suggests that nitrogen loading is important at the site level, and that sources within the 100 meter buffer of salt marshes could have adverse affects.

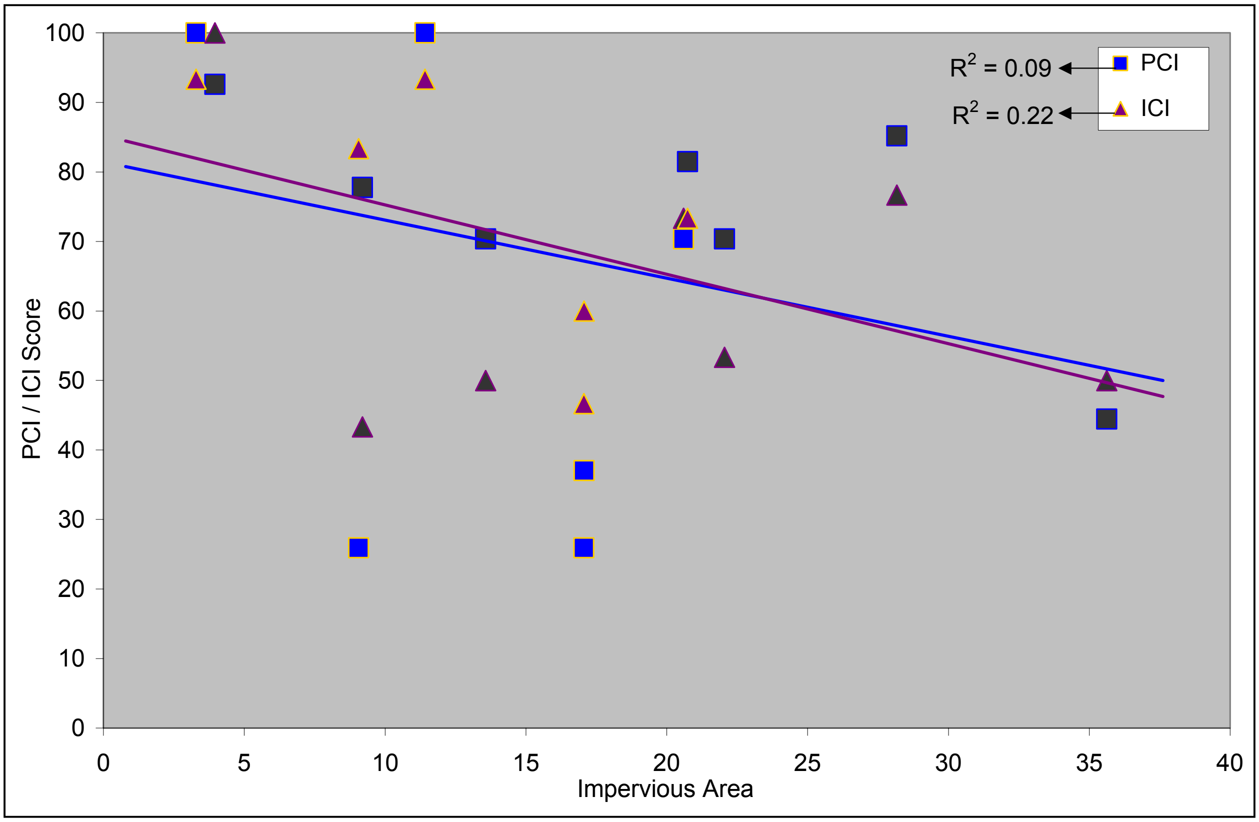

Figure 13. Chart showing relationship between wetland condition and Impervious Area.

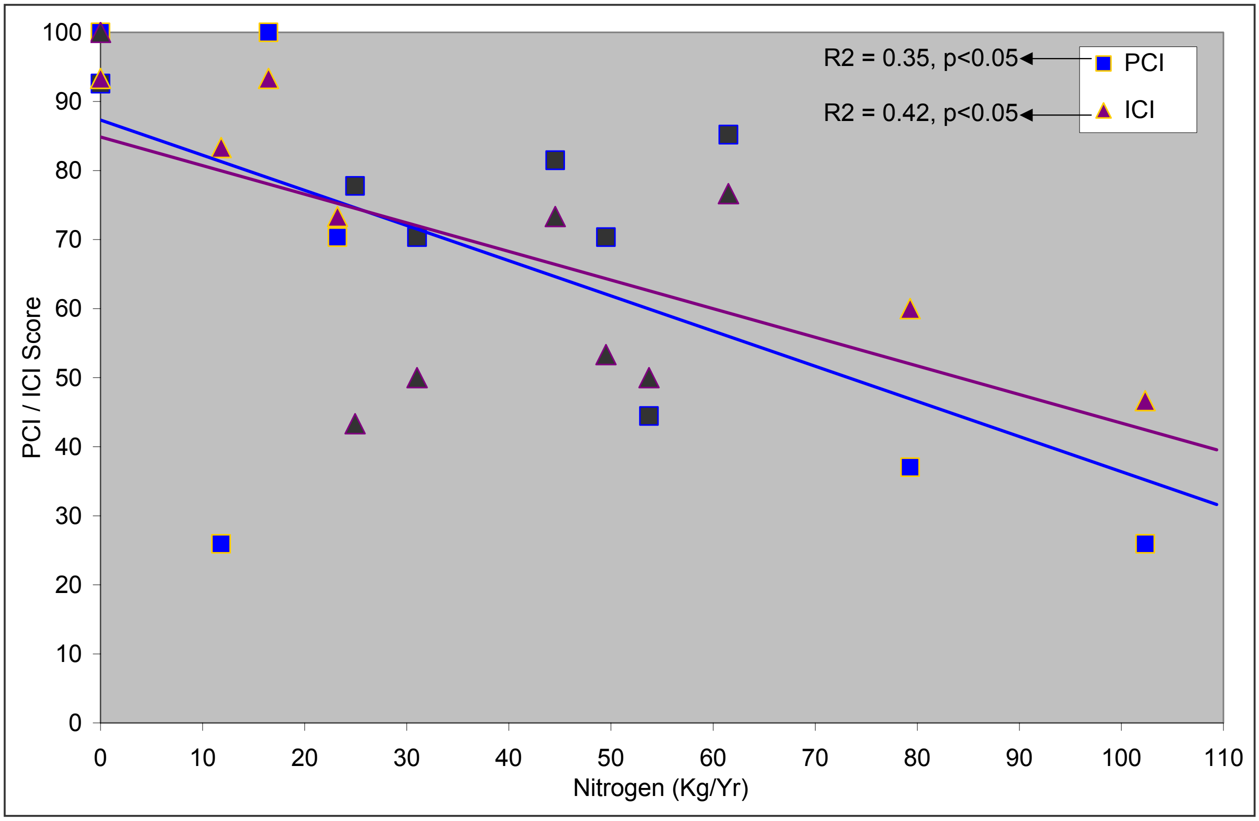

Figure 14. Chart showing relationship between wetland condition and nitrogen load to sites.

The final disturbance indicator was the Land Use Index, actually an integration or combination of a number of different stressors (Figure 15). The LUI incorporates nitrogen, phosphorous and solids loadings, captures impervious area, and includes an on-site assessment component to capture sources not readily picked up by remote sensing techniques.

While there is some scatter around this line and the R^2 values (0.45 PCI and 0.51) are not notably high (but significant at the 99% level), there is a definite steady trend of decreasing biotic condition with increasing human disturbance (land use). This pattern will continue to be examined through future applications of this assessment method but can serve now as a reasonable predictor. Using confidence intervals, one could apply the Land Use Index to a site in question and come with an estimate of biological integrity.

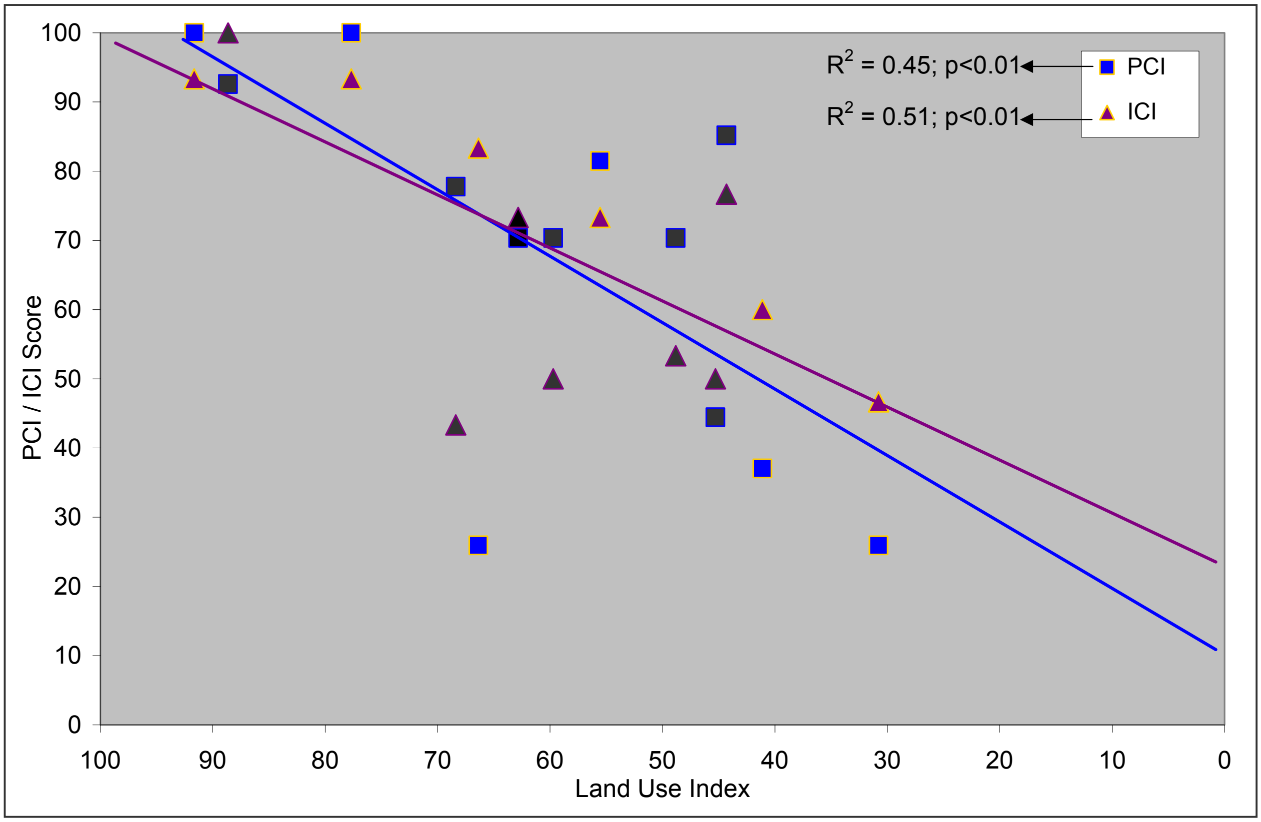

Figure 15. Chart showing relationship between wetland condition and Land Use Index.

Conclusions and Recommendations

A major premise of the assessment of biological community is that the plants and animals will reflect the condition of the waterbody or wetland. When a wetland is adversely affected by human stressors, biological attributes such as taxonomic richness, community structure, trophic structure, and health of individual organisms will change.

Increased attention has been placed on the development of wetland bio-assessment methods, in order to evaluate the condition of wetlands and determine whether these wetlands are maintaining biological integrity (US EPA, 2002a).

Findings from these efforts have documented that wetland condition responds inversely to human stress—that is indicators of biological integrity decline as human stress increases (Blair, 1996; Croonquist and Brooks, 1993; Magee et al., 1999; Wilcox, 1995; and Winter and Duthie, 1998.)

In this investigation, a group of salt marsh wetlands along the southern coast of Cape Cod Bay were selected based on a gradient of human land use stressors. The central intent of the work was to examine whether three indicators of ecological condition co-varied with three indicators of stressors.

For each site we calculated three measures of land use or human disturbance, including: modeled nitrogen and impervious area as well as a multi-indicator method called the Land Use Index. At each site, we also conducted surveys of the plant and invertebrate communities present. Using multi-metric data analysis techniques, we compiled this data into three quantitative indices: a Plant Community Index, an Invertebrate Community Index and a Wetland Ecological Condition Index, which combines the two former indices into a single score.

Recognizing that there are limitations to the investigation and the data—and therefore to the application of the methodology— a number of observations and conclusions have been become evident and are listed here. In addition, the authors also make recommendations for future work .

One of the central findings and implications of this work is that each condition indicator responded inversely and rather predictably to the two of the three disturbance indicators. The best predictor of wetland condition (as represented by plants and invertebrate communities) was the Land Use Index and the next best was modeled nitrogen loading. Surrounding impervious area (i.e. impervious area of the 100m wetland buffer zone) showed limited ability to predict wetland condition.

The biotic indicators (PCI and ICI) also revealed that there were marked differences between the reference sites—with little human disturbances affecting them—and the study sites—with varying degrees of land used and disturbances. Different metrics, both for plant and invertebrates, displayed different signals and the combination of these various indicators into an overall index serves to integrate these characteristics or variables.

More data is needed to further examine these relationships and patterns, either repeat measures at these sites, or through another application of the measures in a new assessment. This work is very resource intensive. For just one year of this investigation, two biotic assemblages and several abiotic parameters were conducted at 6 sites, times multiple stations, times several surveys, so that it becomes clear that field effort and resource needs quickly add up. While, it is true that some parameters require less resources than others, there are still very few funding sources for this type of work. More dialogue needs to occur at policy and funding levels as Federal and State governments decide whether understanding the condition of wetland resources is an important investment.

Some recommendations for future wetland (salt marsh) condition work is to continue to pursue the detailed on-site biotic and abiotic measurements, especially for plants, which in comparison to the invertebrates is less resource-intensive. This is not to say that the invertebrate community should be ignored, but instead to say that with relatively few resources the plant assemblage can be effectively assessed.

The on-site investigation work is very important and helps to reveal and substantiate relationships such as the Land Use Index to wetland condition pattern, but it is also resource intensive and limited in scope. These facts point to an increasing need to explore landscape scale analyses and to look for opportunities to utilize rapid assessment. The dramatic improvement in Geographic Information System (GIS) technology and data has allowed for the development—and the potential development—of a wide range of new tools. Landscape level and rapid assessments allow for a dramatic increase in the scope pf sites that be assessed, moving from a handful of sites to a sub-set or even population basis. This widening in scale coincides with coarser data and therefore assessments, but by building models and verifying and calibrating down to the site-specific intensive applications, these limitations can be addressed and the models can be exploited to make data-supported predictions about condition based on GIS or rapid assessment methods.

MA-CZM plans to engage other partners to explore these new avenues into wetland assessment and looks forward to future collaborations and work in this arena.

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Appendix A

Disturbance Indicator coefficients

LU-21 Code	Land Use Type	Land Use Index	Nitrogen (kg/ha/yr)	Percent Impervious Area
1	CROPLAND	0.77	20.00	0.09
2	PASTURE	0.88	10.00	0.08
3	FOREST	0.97	0.17	0.08
4	NON-FORESTED WETLAND	0.96	0.00	0.05
5	MINING	0.96	7.30	0.07
6	OPEN LAND	0.99	0.17	0.03
7	PARTICIPATION RECREATION	0.78	29.30	0.06
8	SPECTATOR RECREATION	0.82	29.30	0.05
9	WATER BASED RECREATION	0.92	7.30	0.34
10	RESIDENTIAL-MULTI-FAMILY, 3.0 occup	0.12	106.47	0.45
11	RESIDENTIAL-<1/4 AC LOTS, 3.0 occup	0.28	83.64	0.54
12	RESIDENTIAL-1/4 - 1/2 AC, 3.0 occup.	0.54	51.81	0.31
13	RESIDENTIAL->1/2 AC LOTS, 3.0 occup	0.66	24.60	0.3
14	SALT MARSH	0.97	0.00	0.02
15	COMMERCIAL	0.19	121.00	0.64
16	INDUSTRIAL	0.44	15.80	0.55
17	URBAN OPEN	0.81	0.17	0.31
18	TRANSPORTATION	0.29	15.80	0.51
19	WASTE DISPOSAL	0.78	15.80	0.22
20	WATER (fresh)	0.91	0.00	0.03
21	WOODY PERENIAL	0.94	17.6	0.15

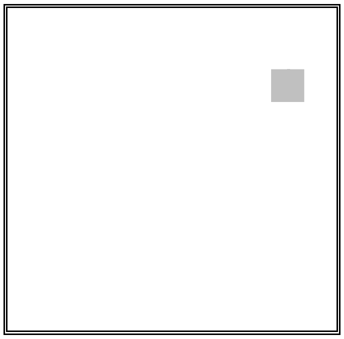
Appendix B

Plant cover class criteria

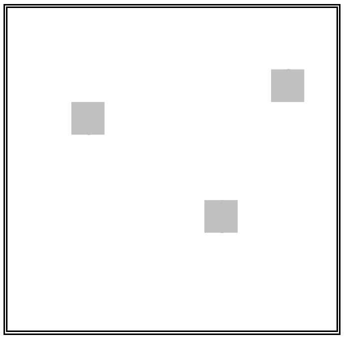
Plant Survey

Standard Cover Classes and Midpoints for Estimating Abundance

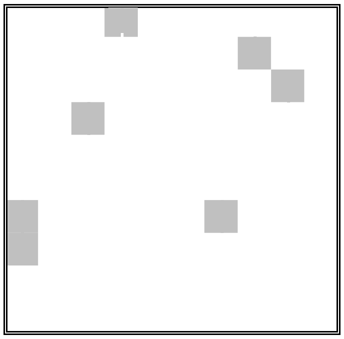
One method for obtaining abundance values for vegetation surveys is to estimate the percent of a plot occupied by the target plant. To assess percent cover, one estimates the area of the plot frame ($1m^2$) that is covered by all of the leaves, branches, and stems of the target species. Visual estimates may vary from one person to another. This variability can be significantly reduced by using standard cover classes and midpoint abundance values. The following figures illustrate 9 standard cover classes to use. For each plot, first identify and list the species present, then for each species determine which figure best describes its cover. Record the midpoint value on the data sheet.



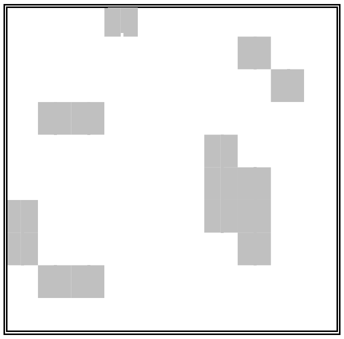
(Trace to 1%)
Use 1%



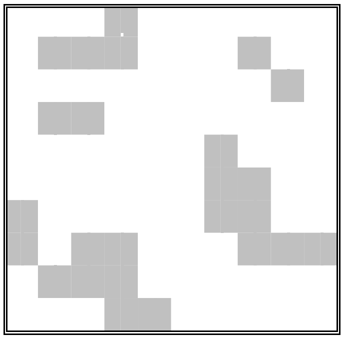
(2% to 4%)
Use midpoint 3%



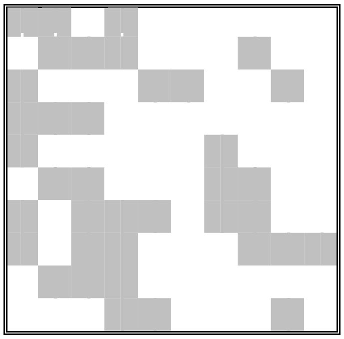
(5% to 10%)
Use midpoint 7%



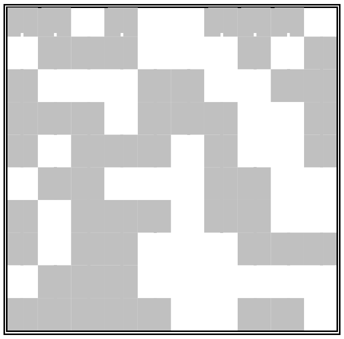
(11% to 19%)
Use midpoint 15%



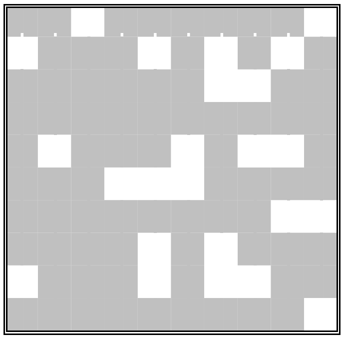
(20% to 30%)
Use midpoint 25%



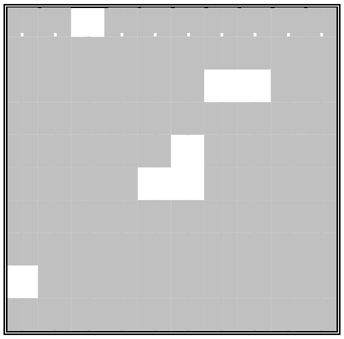
(31% to 45%)
Use midpoint 38%



(46% to 64%)
Use midpoint 55%



(65% to 87%)
Use midpoint 76%



(88% to 100%)
Use midpoint 94%

Appendix C

Plant index metrics and scoring criteria

Genus	**Species**	**Invasive**	**Wet**	**Nutrient**	**Salinity**	**PSL**	**Opp**	**Forb**	**Grass**	**Shrub**	**Vine**	**Introduced**
Achillea	millefolium	0	0.18	0.34	0.4	1	1	1	0	0	0	1
Agropyron(Elytrigia)	pungens	0	0.71	0.34	0.6	1	0	0	1	0	0	1
Agalinis	maritima	0	0.91	0.23	0.6	0	0	1	0	0	0	0
Agrostis	stolonifera	0	0.82	0.34	0.4	0	0	0	1	0	0	0
Amaranthus	cannabinus	0	1	0.45	1	1	0	1	0	0	0	0
Aster	subulatus	0	1	0.34	1	0	0	1	0	0	0	0
Aster	tenuifolius	0	1	0.34	1	1	0	1	0	0	0	0
Atriplex	patula	0	0.82	0.56	0.8	1	0	1	0	0	0	1
Baccharis	halimifolia	0	0.82	0.23	0.8	1	0	0	0	1	0	0
Calystegia	sepium	0	0.4	0.56	0.4	1	1	0	0	0	1	0
Chamaecyparis	thyiodes	0	1	0.12	0.2	1	0	0	0	1	0	0
Chenopodium	rubrum	0	0.82	0.56	0.8	1	0	1	0	0	0	0
Cuscuta	gronovii	0	0.82	0.34	0.4	1	1	1	0	0	0	0
Distichlis	spicata	0	0.91	0.34	1	0	1	0	1	0	0	0
Eleocharis	rostellata	0	1	0.34	0.8	0	0	0	1	0	0	0
Elytrigia(Agropyron)	pungens	0	0.71	0.34	0.6	1	0	0	1	0	0	1
Euthamia	sp.	0	0.82	0.34	0.4	1	1	1	0	0	0	
Festuca	rubra	0	0.09	0.56	0.4	1	1	0	1	0	0	0
Gerardia	maritima	0	0.91	0.23	0.6	0	0	1	0	0	0	0
Glaux	maritima	0	1	0.34	1	0	0	1	0	0	0	0
Iva	frutescens	0	0.91	0.34	0.8	1	0	0	0	1	0	0
Juncus	gerardii	0	0.91	0.34	1	0	0	0	1	0	0	0
Juncus	balticus	0	0.91	0.23	0.8	0	0	0	1	0	0	0
Limonium	nashii	0	1	0.23	1	1	0	1	0	0	0	0
Myrica	cerifera	0	0.5	0.34	0.4	1	1	0	0	1	0	0
Myrica	gale	0	1	0.34	0.4	1	0	0	0	1	0	0
Panicum	virgatum	0	0.5	0.34	0.6	1	1	0	1	0	0	0
Parthenocissus	quinquefolia	0	0.18	0.34	0.2	1	1	0	0	0	1	0
Phragmites	australis	1	0.82	1	0.6	1	1	0	1	0	0	0
Plantago	maritima	0	0.71	0.34	0.6	1	0	1	0	0	0	0
Pluchea	purpurascens	0	0.71	0.34	0.6	1	1	1	0	0	0	0
Polygonum	ramosissimum	0	0.5	0.34	0.4	1	1	1	0	0	0	0
Pontentilla (Argentina)	anserina	0	1	0.34	0.6	1	0	1	0	0	0	0
Pucinella	maritima	0	1	0.34	0.8	0	0	0	1	0	0	0
Rosa	palustris	0	1	0.34	0.4	1	0	0	0	1	0	0
Rosa	rugosa	0	0.09	0.23	0.6	1	0	0	0	1	0	0
Salicornia	europaea	0	1	0.34	1	0	0	1	0	0	0	0
Salicornia	virginica	0	1	0.34	1	0	0	1	0	0	0	0
Salsola	kali	0	0.18	0.34	0.8	0	0	1	0	0	0	0
Scirpus	americanus	0	1	0.34	0.8	1	0	0	1	0	0	0
Scirpus	pungens	0	1	0.34	0.8	1	0	0	1	0	0	0
Scirpus	robustus	0	1	0.34	0.8	1	0	0	1	0	0	0
Setaria	geniculata (parviflora)	0	0.5	0.34	0.6	0	1	0	1	0	0	0
Solanum	dulcamara	1	0.4	0.34	0.4	1	1	0	0	0	1	1
Solidago	sempirvirens	0	0.82	0.34	0.8	1	1	1	0	0	0	0
Spartina	alterniflora	0	1	0.34	1	1	0	0	1	0	0	0
Spartina	cynosuroides	0	1	0.34	0.8	1	0	0	1	0	0	0

Genus	Species	Invasive	Wet	Nutrient	Salinity	PSL	Opp	Forb	Grass	Shrub	Vine	Introduced
Spartina	patens	0	0.91	0.34	1	0	0	0	1	0	0	0
Spartina	pectinata	0	1	0.34	0.4	1	0	0	1	0	0	0
Suaeda	linearis	0	1	0.34	0.8	0	0	1	0	0	0	0
Teucrium	canadense	0	0.71	0.34	0.4	1	1	1	0	0	0	0
Thelypteris	thelypteroides	0	0.91	0.34	0.4	0	0	1	0	0	0	0
Toxicodendron	radicans	0	0.5	0.34	0.4	1	1	0	0	1	1	0
Triglochin	maritimum	0	1	0.34	1	0	0	0	1	0	0	0
Typha	angustifolia	0	1	0.67	0.6	1	0	1	0	0	0	0
Vitis	aestivalis	0	0.18	0.34	0.4	1	1	0	0	0	1	0

Cape Plants 1999								
METRIC	**BGIC-ref**	**EMBR-Ref**	**Ref Avg**	**ECNW**	**BPC**	**SMC**	**EOBP1**	**stn dev**
Community Similarity	100.00	100.00	100.00	90.91	64.29	77.78	71.43	15.13
Score	**6**	**6**		**6**	**2**	**4**	**4**	
Taxa Richness	16	13	15	11	14	9	7	
Absolute Difference	2	2	0	4	1	6	8	2.71
Score	**6**	**6**		**4**	**6**	**4**	**2**	
Invasive Species	2.64	0.00	1.32	0.00	29.63	22.78	21.28	13.31
Score	**6**	**6**		**6**	**2**	**4**	**4**	
Nutrient Affinity	35.88	34.39	35.14	33.88	53.62	49.09	48.04	8.74
Score	**6**	**6**		**6**	**2**	**2**	**2**	
Salinity Tolerance	98.34	98.07	98.21	93.00	82.62	90.69	90.99	5.80
Score	**6**	**6**		**4**	**0**	**4**	**4**	
Persistent Standing Litter	68.18	58.13	63.16	33.49	62.80	63.00	27.54	17.19
Score	**4**	**6**		**6**	**4**	**4**	**6**	
Opportunistic Species	15.92	10.28	13.10	6.94	46.63	23.65	23.08	14.19
Score	**6**	**6**		**6**	**0**	**4**	**4**	
Habitat Affinity	80.66	81.94	81.30	78.98	58.95	67.87	68.52	9.14
Score	**6**	**6**		**4**	**0**	**2**	**2**	
IVI Scores	**95.83**	**100.00**		**87.50**	**33.33**	**58.33**	**58.33**	72.22

	Biological Condition Scoring Criteria				
METRIC	**0**	**2**	**4**	**6**	SD
Community Similarity	<55	55-69	70-85	>85	15
Taxa Richness	>=11	8-11	4-7	<=3	3
Abn. Invasive	>51	26-50	6-25	<=5	13
Abn. Nutrient	>56	47-56	37-46	<=36	9
Abn. Salinity	<=83	84-89	90-96	>=97	6
Abn. PSL	>98	81-98	63-80	<63	17
Abn. Opportunistic	>45	31-45	17-30	<16	14
Abn. Hab-Aff	<61	61-70	71-80	>80	9

Appendix D

Invertebrate index metrics and scoring criteria

	BGIC-Ref	EBMR-Ref	Ref-Value	ECNW	BPC	SMC	EOBP1	stnd_dev
May Total Taxa Richness	17	11	14	17	8	11	17	3.64
Aug Total Taxa Richness	24	13	18.5	17	22	16	22	3.92
Total (New) Taxa Richness	32	17	24.5	21	25	20	30	5.40
BCSC Score	6	4	6	6	6	6	6	0.76
May % Predators	0.50	5.62	3.06	10.45	0.20	0.36	2.50	3.73
Aug % Predators	6.3	0	3.2	0.2	0.7	0.2	1.1	2.31
% Predators	3.4	2.8	3.1	5.3	0.5	0.3	1.8	1.77
BCSC Score	6	4	6	6	0	0	2	2.76
May % Contribution Dominant Taxa Group	81	64	72	37	46	60	57	14.88
Aug % Contribution Dominant Taxa Group	64.7	28.2	46.5	64	57.8	78.2	68.8	16.46
Contribution Dominant Taxa Group	73	46	59	50	52	69	63	9.91
BCSC Score	2	6	6	6	6	4	4	1.57
May % Contribution Dominant Trophic Group	83	66	75	50	46	60	66	13.18
Aug % Contribution Dominant Trophic Group	78.9	40.8	59.9	64.3	59.6	62.7	74.5	12.26
% Contribution Dominant Trophic Group	81	53	67	57	53	61	70	10.30
BCSC Score	2	6	6	6	6	6	4	1.57
May % Abundant	5.9	9.1	7.5	5.9	37.5	27.3	5.9	12.86
Aug % Abundant	16.7	0	8.4	17.6	18.2	18.8	4.5	7.66
% Abundant	11	5	8	12	28	23	5	8.98
BCSC Score	4	6	6	4	2	2	6	1.80
May % Rare	59	54	57	53	38	64	59	8.32
Aug % Rare	41.7	51.8	46.8	47.1	56.3	59.1	51.0	5.95
% Rare	50	53	52	50	47	61	55	4.61
BCSC Score	4	6	6	4	4	6	6	1.07
May % Palaemonidae Shrimp	0	0	0	15.13	0	0	3.75	5.66
Aug % Palaemonidae Shrimp	0	27.5	13.8	64.0	0	0	68.8	30.13
% Palaemonidae Shrimp	0	14	7	40	0	0	36	17.26
BCSC Score	6	4	6	2	6	6	2	1.90
May % Introduced Species	0.01	1.67	0.84	10.08	0	0	3.75	3.67
Aug % Introduced Species	0.1	3.5	1.8	2.1	0	0.2	0.8	1.31
% Introduced Species	0	3	1	6	0	0	2	2.19
BCSC Score	6	4	6	4	6	6	4	1.07
May Community Taxa Similarity Index	100	100	100	57	52	53	68	23.22
Aug Community Taxa Similarity Index	100	100	100.0	29.5	26.0	19.7	39.4	38.58
Community Taxa Similarity Index	100	100	100	43	39	36	54	30.86
BCSC Score	6	6	6	4	2	2	4	1.80
May Community Trophic Index	45.0	42.3	43.7	44.2	42.9	54.4	54.4	5.35
Aug Community Trophic Index	52.3	47.6	49.9	38.8	57.4	34.0	44.6	7.99
Community Trophic Index	69.4	69.5	69.4	48.8	48.2	41.7	67.3	12.34
BCSC Score	6	6	6	2	2	0	4	2.43
Subtotal	48	52	60	44	40	38	42	
ICI Score	80.00	86.67	100.00	73.33	66.67	63.33	70.00	

	Biological Condition Scoring Criteria					
Metric	**0**	**2**	**4**	**6**	**Ref Avg**	**stnd dev**
Taxa Richness	<8	8-13	14-19	20+	25	5
% Predators	<1.1	1.1 - 2.0	2.1 - 2.9	3+	3.1	1.8
Contribution Dominant Taxa Group	>79	70-79	60-69	<60	59	10
% Contribution Dominant Trophic Group	>87	78-87	68-77	<68	67	10
% Abundant	>28	19-28	9-18	<9	8	9
% Rare	<40	40-45	46-51	52+	52	5
% Palaemonidae Shrimp	>43	26-43	8-25	<8	7	17
% Introduced Species	>24	8-24	2-7	<2	1	2
Community Taxa Similarity Index	<10	10-39	40-69	70-100	100	31
Community Trophic Index	<43	43-55	56-68	>69	69	12