PART I
Monitoring Cape Cod Bay

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Water Quality

In 2006, the Cape Cod Bay Monitoring Program was established by the Provincetown Center for Coastal Studies (PCCS) as a long-term study to investigate the health of the Bay from an ecosystem perspective. Cape Cod Bay, like other coastal ecosystems, is at risk to succumbing to the adverse effects of the increasing demands of a growing population. Cape Cod is one of the regions of the highest rate of population increase. In the early 1950s, the population of Barnstable County was less than 50,000. Today, the number of residents has more than quadrupled to greater than 220,000 (US Census Bureau). With this population growth comes dramatic changes in land use and land cover with commercial and residential developments replacing what were once forested areas and other natural habitats (WHRC).

Impacts on the Bay related to population growth are thus both direct and indirect. Direct effects include increased sewage (i.e. point source pollution) and are relatively easy to monitor. The impacts of indirect effects are much more difficult to detect and/or measure. For example, associated with increased commercial and residential development are larger areas of impervious surfaces (e.g. paved roads, parking lots, and driveways; buildings; tanks; recreational courts). Impervious surfaces are one of the primary sources of non-point source pollution. When rain water or snow melt washes over these surfaces, pollutants (e.g. heavy metals, gas, oil, pet waste, fertilizers) are picked up, accumulated, and carried to storm drains, rivers, streams, and wetlands, ultimately to be deposited in the Bay. On Cape Cod, these non-point source pollutants are thought to be the leading cause of water quality degradation (USEPA, WHRC).

Therefore, as more and more people come to Cape Cod, whether to visit or to reside, it is critical that we preserve that which attracts these people – the beauty of the surrounding waters, the diversity of marine life - and protect these waters from the degradation prevalent in so many other coastal ecosystems. With this as the ultimate goal of the Cape Cod Monitoring Program, the following objectives were established:

- Provide baseline water quality data for Cape Cod Bay
- Map the distribution of nutrients both nearshore and offshore
- Identify sources of pollution (nitrogen, phosphate)
- Trace spatial (horizontal, vertical) and temporal (tidal, seasonal, interannual) changes in water properties and nutrient concentrations
- Develop a set of parameters that can serve as indicators of the health of the Cape Cod Bay ecosystem.

Citizen Scientists aboard R/V *Alert* at the April 2007 Monitoring Field Season Launch

Monitoring Variables

The variables chosen in the first year of this study to address the water quality of Cape Cod Bay include the following chemical and physical parameters as recommended by other water quality monitoring studies (e.g. Coalition for Buzzards Bay, URI Watershed Watch, EPA).

Physical Measures

Water **temperature** and **salinity** are two of the most important physical properties of the marine environment, influencing many physical (density), chemical (capacity to hold D.O., sensitivity to toxic wastes), and biological processes (metabolic processes, photosynthesis) as well as dictating the types, distribution and abundance of marine flora and fauna. Monitoring levels of these properties, and more importantly, changes in the levels, provides a direct indication of potential problems.

PCCS Hiebert Marine Laboratory

Turbidity, a measure of water clarity or how much the material suspended in the water column decreases light penetration, is also measured as an indicator of the quality of the water in the Bay. High levels of turbidity can result from anthropogenic disturbances such as urban runoff, waste discharge, dredging, and boating, as well as natural disturbances such as storms, wave action, and bottom feeding animals. Highly turbid waters are detrimental to the entire ecosystem from sediment quality, to water chemistry, to the survival of plants and animals. Some of the associated negative impacts of high levels of turbidity include lowering the rates of photosynthesis, smothering benthic organisms, and altering bottom material and sediment size.

Amy Costa, Ph.D., conducts water sampling testing in Cape Cod Bay during the '06 field season

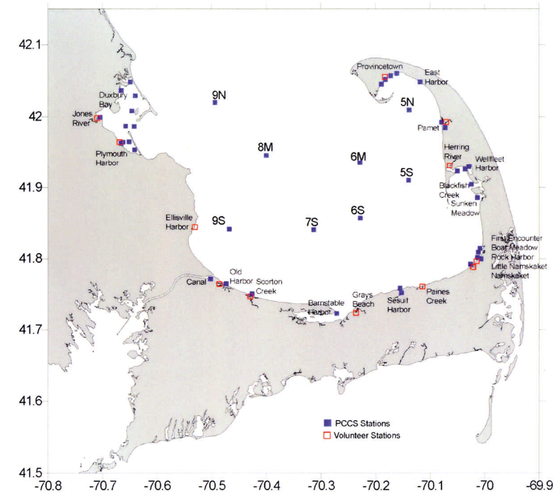
Chemical Parameters

Excessive nutrient input is behind most major problems affecting coastal ecosystems, (e.g., eutrophication, algal blooms, hypoxia). It is therefore important that baseline data for the Bay is established and both small and large-scale nutrient fluxes (spatial and temporal) are closely monitored. The nutrients of interest to this project are nitrogen and phosphorous. During the first year of data collection, water samples were analyzed for dissolved inorganic forms of nitrogen (NOx) and phosphorous (PO4). These represent the bio-available forms of N and P or those forms immediately available to organisms for growth. During 2007 samples will also be analyzed for levels of of total nitrogen, total phosphorous, and ammonia.

Other associated chemical water quality parameters that were monitored included **dissolved oxygen** (D.O.) and **pH**. D.O. concentrations are a measure of how well the water is aerated. This parameter is one of the best and most immediate indicators of a system's health. Because oxygen is needed to support animal and plant life, consequences of declining D.O. levels will set in quickly. This immediate impact on plant and animal life makes measuring the level of oxygen an important means of assessing water quality. Additionally, at low oxygen conditions, nutrients (and other pollutants) will be released from sediments thereby exacerbating problems. pH levels are also critical to survival of most marine plants and animals. They can be influenced by events such as algal blooms and acidic pollution from wastewater discharge and in this way function as preliminary indicators of potential problems. At low pH levels, toxic metals in sediments can be re-suspended in the water column. Therefore, it is important to monitor pH levels in areas of concern (e.g. dredge spoil, harbors, marinas).

For the 2007 field season, the measurement of **chlorophyll a** in surface samples was added to the sampling regime. Chlorophyll a is the green photosynthetic pigment in most phytoplankton and plant cells. Because of the direct relation between chlorophyll a and algal concentration, measuring chlorophyll a will give an accurate estimation of the amount of organic matter produced.

Taken as a whole, this set of measurements provides a picture of the condition of the Bay ecosystem by functioning as an early warning system (temperature, salinity, pH), tracing the changes in levels of contaminants (nutrients, turbidity), and predicting the status of the plant and animal life (dissolved oxygen, chlorophyll a).



2006 Station Locations

Figure 1. Locations of monitoring stations sampled during 2006. Water quality sampling was conducted both from shore by trained volunteers and from PCCS research vessels (R/V *Alert* and R/V *Shackleton*) by staff.

Data Analysis: Health Index During the 2006 field season, over 1500 samples were collected and analyzed for water quality data. To present a summary of the data for each station, a health index was calculated for all stations sampled in Cape Cod Bay during the 2006 field season. The concept behind this index followed the examples provided by the Coalition for Buzzards Bay and the Mystic River Watershed Association. The index for Cape Cod Bay stations was based on data collected from the surface waters during ebb tide. Water temperature, dissolved oxygen, turbidity, and nitrate/nitrite concentrations were used to calculate the health index (Table 1). Each station was given a rating for each season (spring, summer, and fall). The spring health index was calculated using all samples taken during April and May. The summer index used all data from samples taken during June, July, and August. The fall index was based on data from all samples taken during September and October. Each station was categorized as good, fair, or poor based on the parameters given in Table 1. As more data are gathered in successive years, this index will likely be modified. This is therefore only a first attempt at evaluating the health of the areas monitored.

Health Index	Temperature (°C)	Dissolved Oxygen (mg/L)	Turbidity / Secchi Depth (m)	Nitrate/Nitrite (µM)
Good	<18	>8	>5	<1
Fair	18-21	6-8	3-5	1-5
Poor	>21	<6	<3	>5

Table 1. Levels for each water quality parameter used to estimate health indices for each station.

No data were collected from stations from Provincetown to Pamet during the spring. No volunteers sampled during spring. Most of the stations that were sampled during the spring fell into the Good category (Figure 2). The stations surrounding Plymouth Harbor were scored Fair as a result of their poor water clarity and slightly higher levels of nitrate/nitrite.

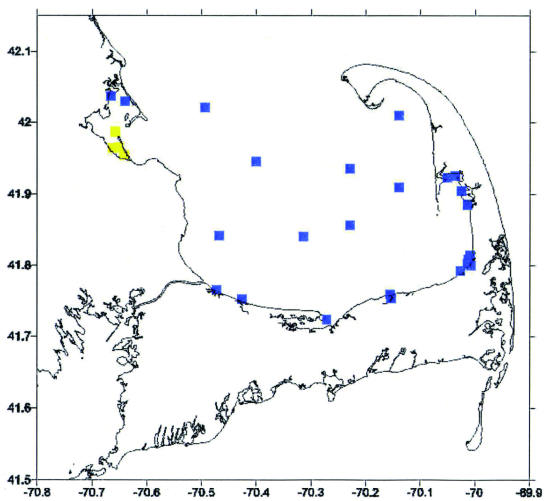


Figure 2. Health index calculated for stations sampled during the spring months. Blue represents good; yellow represents fair; red represents poor.

Conditions deteriorated considerably during the summer at stations located along the shoreline of Cape Cod (Figure 3). Only one station located outside Sesuit Harbor, was rated Good. Most stations were adversely affected by more than one parameter. Of the eight offshore stations, all but the most southwestern one, 9S, were considered Good. 9S received a Fair rating as a result of its warmer temperature and lower water clarity.

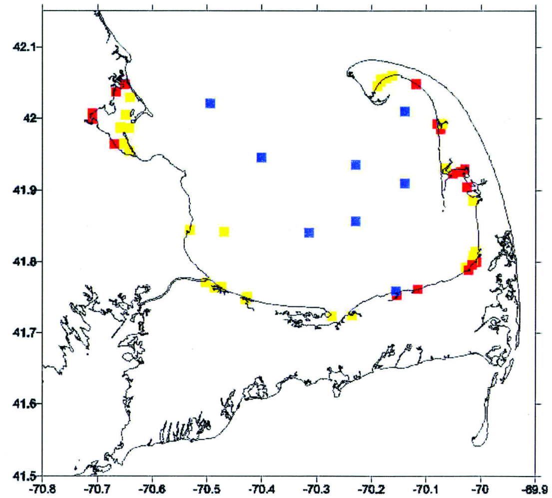


Figure 3. Health index calculated for stations sampled during the summer months. Blue represents good; yellow represents fair; red represents poor.

Although not as good as conditions during the spring, for most stations, water quality improved during the fall (Figure 4). Only Jones River and the inshore stations at Old Harbor and Scorton Creek remained Poor as a result of high levels of nitrate/nitrite.

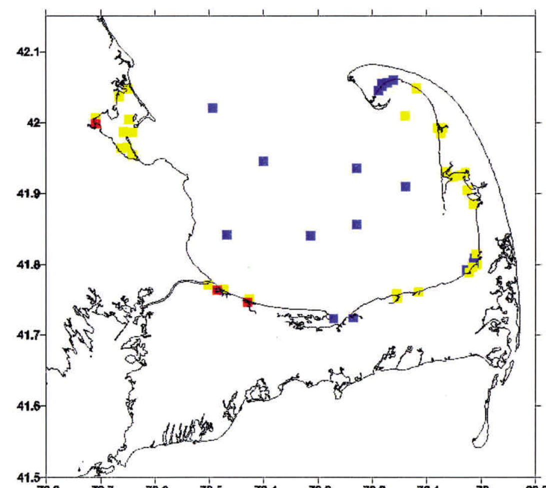
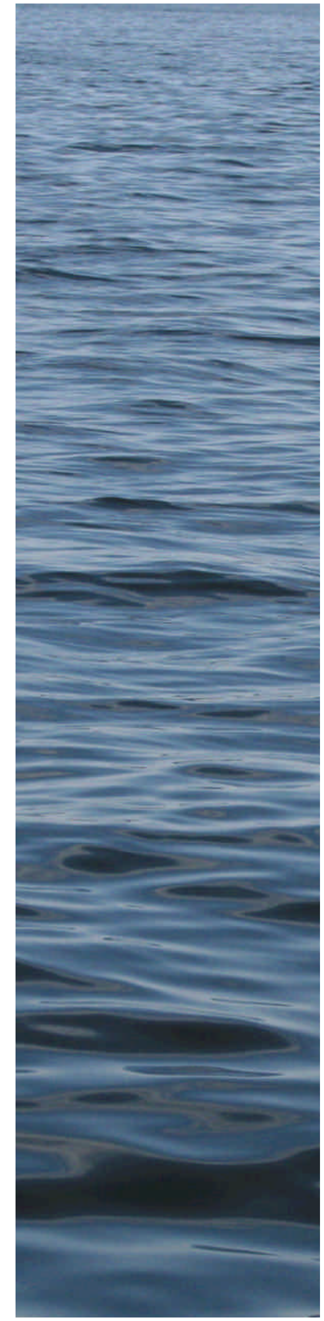


Figure 4. Health index calculated for stations sampled during the fall months. Blue represents good; yellow represents fair; red represents poor.



Summary

With the completed analyses of only one field season of data, only very tenuous assumptions can be made about the health of Cape Cod Bay. The data from this first season suggest that during much of the year, the Bay is relatively healthy. During the summer months, however, coincident with the population explosion, water quality conditions begin to deteriorate. Dissolved oxygen levels decline. Nitrate/nitrite concentrations increase dramatically, especially in surface waters during ebb tide. Ortho-phosphate concentrations increase. Water clarity declines. These trends are especially evident at nearshore and inshore stations. Both the spatial and temporal variability in the water quality data therefore suggest that the anthropogenic influences are negatively impacting Cape Cod Bay. A preliminary analysis of the 2007 data collected to date show similar patterns in peaks in nutrient concentrations and declines in dissolved oxygen levels and water clarity during the summer months.

It is imperative, therefore, that over the coming years, as impacts of population growth continue to manifest themselves on Cape Cod, that the waters of the Bay are closely monitored. It is only through careful documentation and analyses of trends in water quality data that the health of the Bay can be understood. It is only after we understand this dynamic and fragile system that we can take suitable steps to protect it.

PCCS is partnering with LightHawk, a non-profit aviation organization, dedicated to championing environmental issues through flight. Recent flights over Cape Cod Bay with the Monitoring Program have assisted with the assessment, photographic documentation, and monitoring of eelgrass in the Bay. Pictured above is Captain Marc Costa.

Image courtesy of Amy Costa/PCCS/LightHawk

Citizen Scientists

Citizen Scientist Aimee Teaby
Photo courtesy of Aimee Teaby

Since the onset of the program, volunteers have been a critical component to the collection of water quality data along the Cape Cod Bay shoreline. Volunteer Citizen Scientists sample sites from Provincetown to Plymouth once a week, May - October, during mid-ebb tide. These sites are located further inshore in areas inaccessible by boat. Data on temperature, salinity, turbidity, dissolved oxygen, pH, and nutrients are collected. The involvement of the volunteers and the amount of data contributed by them has benefited the program immensely. We hope to expand the network of volunteers and the number of sites each year.

Citizen Scientist	Site	2006	2007
Aimee Teaby	Provinctown Harbor Herring River	Jun-Sept	
Karen Kramer	Pamet	Jun-Jul	
Nina Kaars	Herring River		May-Oct
Phil and Betty Suraci	Boat Meadow		May-Oct
Joann Figueras	Little Namskaket	Jun-Oct	May-Oct
Scott and Heather Grenon	Upper Namskaket		May-Aug
Val Magor	Namskaket	Jun-Oct	May-Sept
Keith Harrison	Cole Road Beach		May-Oct
Bill Edwards	Paines Creek	Jun-Nov	May-Nov
Theresa Barbo	Grays Beach	Jun-Nov	
Diana Stinson	Scorton Creek Old Harbor	Jun-Dec	Jun-Dec
Regina Asmutis-Silvia	Ellisville Harbor Plymouth Harbor	Jun-Sept	Jun-Sept
Carol "Krill" Carson	Jones River	Jun-Nov	May-Nov

Eelgrass

Eelgrass ecosystems are a vital part of coastal embayments such as Cape Cod Bay. They are highly productive systems and extremely important biologically. They act as a refuge and nursery for juvenile fish and shellfish, many of which are commercially important species in this region. The individual eelgrass blades function as an important substrate, being colonized by a diverse community of epiphytic flora and fauna. Because of these attributes, eelgrass beds typically support a higher diversity and abundance of marine life compared to surrounding unvegetated areas. Eelgrass systems are equally important from a purely physical perspective in that they help to prevent erosion by stabilizing sediments with their extensive root systems as well as aid in filtering contaminants from the water column.

Despite the obvious value of eelgrass ecosystems, eelgrass beds are threatened by a number of anthropogenic perturbations. Declines in seagrass populations have been linked to physical disturbances (i.e., dredging, construction, shellfishing, propeller damage from boating), turbidity (i.e. topsoil runoff, activities that resuspend sediments), pollution, and most notably, eutrophication as a result of nutrient loading.

Eelgrass is often used as an in situ indicator of the condition of the entire ecosystem because it responds noticeably to any degradation in water quality, typically by declining in range or abundance. Therefore, because of this close association between eelgrass and water quality, monitoring the eelgrass habitat of Cape Cod along with water quality will give us a better understanding of the dynamics of this system.

Specific objectives include of our research include:

- Describe the flora and fauna indigenous to the eelgrass ecosystem of Cape Cod Bay
- Measure the productivity of the eelgrass population of Cape Cod Bay
- Map current eelgrass beds in Cape Cod Bay on a finer scale
- Set up a long-term program to monitor the effects of anthropogenic and natural disturbances on the abundance and distribution of eelgrass within Cape Cod Bay

During the 2006 field season, boat-based surveys were used to investigate eelgrass beds off of Jeremy Point, Billingsgate Island, and Plymouth. In 2007, through a collaboration with LightHawk, 2 aerial surveys have been flown to photo-document the eelgrass beds of the entire Bay. Preliminary analyses of these photographs have shown areas that appear to be healthy and flourishing as well as areas that are exposed to recurrent physical destruction from commercial fishing practices.

Ultimately, the data collected from both boat and aerial surveys will enable us to characterize the present status of the major eelgrass beds in Cape Cod Bay and give tangible evidence of the ecological importance of this ecosystem in terms of productivity, habitat, refuge, and feeding ground. With the results of this study, we will be able to more fully interpret the influences of urbanization on the Bay and the degree to which they penetrate into the surrounding eelgrass beds. Once the relative importance of this environment is established and the threats are quantified, we will have a basis for managing for the protection of this resource. Additionally, with data on water quality (nutrient concentrations, light penetration), sediment type, and historical distribution of eelgrass, we will be able to target potential areas for restoration efforts.

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Aerial photograph of Provincetown Harbor showing evidence of physical disturbance of eelgrass beds. Each circular bare patch is a mooring chain scar where eelgrass around the mooring has been cleared by the mooring chain dragging along the bottom. Image courtesy of Marc Costa/PCCS/LightHawk

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