A NOVEL WATER QUALITY MONITORING PROGRAM
FOR NANTUCKET SOUND:

Plan Development for the Cape Cod Commercial Hook
Fishermen’s Association

by

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Date:________________

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ABSTRACT

Water quality in Nantucket Sound has historically been viewed as pristine and un-polluted; however, in recent years signs of non-point source pollution have become evident. Proliferation of nuisance algae and declines in fish stock have led to a belief amongst local citizens that the waters of Nantucket Sound are no longer as clean as previously thought. The objective of this project was to develop a water quality monitoring program for Nantucket Sound to establish a baseline for conducting future water quality assessments. Through volunteering with the National Park Service and conducting online research a water quality monitoring program was established.

Working with the Cape Cod Commercial Fisherman’s Association I determined the feasibility of using fishers’ vessels as monitoring platforms for conducting water quality research in Nantucket Sound. Fishers’ skills, knowledge and increasing awareness as stewards of ocean resources suggest they can be important assets for water quality monitoring efforts.

The plan describes water quality parameters that will be measured, monitoring sites and frequency, fisher teams, field protocol, and quality control. Furthermore, estimated costs for the project are presented and responsibility for data management and analysis are addressed. This plan aims to provide a basic framework and guidelines for monitoring water quality in Nantucket Sound and is open to further recommendations and revisions.
ACKNOWLEDGEMENTS

I would like to thank the Cape Cod Commercial Hook Fishermens’ Association for providing me the opportunity to develop this plan. Thank you to the National Park Service for allowing me to volunteer on water quality monitoring projects on Cape Cod. Thank you to the fishermen who offered their input and ideas. I would also like to thank my advisor, Dr. Bill Kirby-Smith for his helpful suggestions. And finally thanks to all my friends and family who have supported me every step along the way.
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Introduction:

In the United States there have been extensive accounts of coastal ecosystem degradation from non-point source pollution (agricultural and storm-water runoff). Areas such as Chesapeake Bay, the “Dead Zone” in the Gulf of Mexico and Waquoit Bay off Cape Cod have all experienced the negative impacts of nutrient loading and eutrophication caused by diffuse pollution. Indications of pollution in these ecosystems (algal blooms, depletions in fish stocks, etc.) have become increasingly noticeable in Nantucket Sound – a relatively pristine body of water South of Cape Cod. In order to ensure that Nantucket Sound does not meet the fate of its eutrophic counterparts the status of its waters must be assessed. The focus of this project was to develop a comprehensive water quality monitoring program for Nantucket Sound in order to establish a baseline to better understand the health of the environment.

Nutrient loading and eutrophication:

Non-point source pollution leads to nutrient loading and can cause eutrophication of marine waters. Before explaining the details of the water quality plan and how it was developed, background information on nutrient loading and eutrophication will be provided.

Nutrient loading, as the term implies, is an increase in the concentration of a specific nutrient(s) in the environment. It is often the case that nutrient loading is associated with limiting nutrients. These are nutrients that are in shortest supply, which control the amount of primary production of phytoplankton (in some cases macroalgae or macrophytes) that exist in the aquatic environment (Boesch 2002). Increased concentrations of limiting nutrients in the marine environment have been shown to increase primary productivity in the form of floral biomass (Smith 1998, Boesch 2002). The major limiting nutrient in coastal systems is nitrogen whereas phosphorus is limiting in freshwater environments (Howarth et al. 1996, Nixon 1996).
While nitrogen loading also occurs naturally from terrestrial runoff of wildlife waste, anthropogenic sources have greatly contributed to the high concentrations of nitrogen found in various coastal environments (Nixon 1995). Specifically, greater use of fertilizers for farming has resulted in increased nitrogen loading in marine environments from subsequent riparian input and stormwater runoff. Nixon (1995) explains that anthropogenic fluxes of nitrogen are now very significant compared to the natural flows in a number of coastal ecosystems.

Between 1960 and 1980 there was a rapid growth of world fertilizer use as well as increased emissions of nitrogen oxides from fossil fuel combustion (Boesch 2002). This period coincided with the occurrence of an increase in hypoxic conditions\(^1\) over large coastal ecosystems where phytoplankton production was observed to be doubling (Vitousek 1997), and benthic macrophyte meadows were contracting due to shading by phytoplankton (Boesch 2002). These events provide compelling evidence that nutrient loading was affecting the coastal environment.

When the concentration of a limiting nutrient increases due to a nutrient loading event (i.e. point pollution discharge or runoff) the most probable response is an increase in primary productivity given that other environmental conditions such as light exposure and other nutrient requirements are met\(^2\) (Nixon 1995). This increase in primary productivity results in an increased rate of supply of organic material to an ecosystem, which Nixon (1995) defines as eutrophication. There are different uses for this term; however, this definition provided by Nixon (1995) will be utilized for this project.

Many definitions of eutrophication describe it as nutrient enrichment (Smith et al. 1999; Boesch 2002; Novotny 2003). However, Nixon (1995) points out that nutrient enrichment, in

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\(^1\) A state of oxygen deficiency where dissolved oxygen < 2 mg l\(^{-1}\) (McClellan 2006)

\(^2\) Primary productivity varies throughout the year because required environmental conditions, such as light exposure, experience seasonal fluctuations.
addition to a decrease in turbidity and decline in grazing pressure, are causes of eutrophication and are not the phenomenon itself. Nixon emphasizes that out of all these factors nutrient loading is the most prevalent cause of eutrophication. Also, Nixon (1995) clarifies that changes associated with or even caused by the increase in the supply of organic carbon (for example, species changes, hypoxia, fish kills) is not eutrophication, but its effects.

Eutrophication is a process and should not be confused as a trophic state. Nixon (1995) describes a water-body can be eutrophic (meaning that it has a certain concentration of organic material ranging between 301-500 g C m⁻²y⁻¹); however it does not necessarily have to be experiencing eutrophication. In other words, the ecosystem is not undergoing an increase in organic matter.

Eutrophication can negatively impact the coastal ecosystem in various ways. First, it can cause declines in coral reef communities and lower the perceived esthetic value of the environment (Carpenter et al. 1998). Also, some negative consequences are associated with changes in primary productivity and plant life such as: an increase in phytoplankton biomass, increased blooms in gelatinous zooplankton, increased blooms of benthic algae and changes in macrophyte species and biomass. These increased blooms consequently deplete oxygen levels through the decomposition of dead zooplankton and nuisance plants by bacteria (Carpenter et al. 1998). The depletion of oxygen eventually leads to hypoxic conditions, which causes some marine environments to be unsustainable for certain finfish and shellfish species³. In the event that species fail to find areas of higher oxygen concentration, losses of harvestable finfish and shellfish species can occur (Smith 1999, Breitburg et al. 1999). High fishery mortalities have

³ Since primary productivity undergoes seasonal fluctuations, hypoxia intensity will likewise vary throughout the year.
consequently disrupted coastal ecologies in a number of areas such as Waquoit Bay and
Chesapeake Bay (Bown and Valliela 2001, Breitburg et al. 2001, respectively).

Another adverse effect from eutrophication is the formation of toxic algal blooms (red or
brown tides). These blooms release deadly toxins that can be harmful to both human and marine
species’ health (Carpenter et al. 1998). Burkholder et al. (1992) discovered a toxic bloom
species was responsible for killing off large numbers of striped bass (Morone saxatilis) and
summer flounder (Paralichthys lethostigma) off the North Carolina coast and also suggested it
may cause long-term neurological damage in humans. Additional research has found that other
negative effects resulting from red and brown tides are shellfish poisoning in humans and
significant mortality in marine mammals (Anderson 1994).

Nantucket Sound

Nantucket Sound has a total area of approximately 163 nautical square miles and is
located between Cape Cod, Vineyard Sound, the islands of Martha’s Vineyard and Nantucket
Islands. The latitudinal boundary spans from 41°12’ N to 41°40’ N, while the longitudinal bound
is approximately from 69°55’W to 70°36’W. The Atlantic Shelf borders Nantucket Sound to the
east, and the deeper Atlantic Shelf waters are to the south (Figure 1). The submerged land within
3 miles from mean low water is within the boundaries of the Cape and Islands Ocean Sanctuary.
Monomoy National Wildlife Refuge comprises the northeastern terrestrial boundary of the
Sound (Review of the State and Federal Marine Protection of the Ecological Resources of
Nantucket Sound 2003).
Nantucket Sound is situated in a unique location where the cold Labrador current meets the warm waters of the Gulf Stream. This area represents the southern range for Northern Atlantic species habitat and the northern bound for Mid-Atlantic species - making Nantucket Sound an area of extreme richness in biological diversity, characterized by habitats ranging from open sea to salt marshes. These habitats are utilized by many federal and state protected species including piping plovers, roseate terns, leatherback sea turtles, grey seals, and loggerhead sea turtles. The complex networks of habitat use and species competition within the Sound remains an area for significant research (Review of the State and Federal Marine Protection of the Ecological Resources of Nantucket Sound 2003).

Historically, there has been minimal effort to monitor water quality in Nantucket Sound. Data has been collected from some estuarine systems that feed into the Sound (Bowen and Valiella 2001) and other projects such as with the Woods Hole Oceanographic Institute (WHOI) have started collecting water quality data opportunistically from ferries that shuttle people from
Cape Cod to Martha’s Vineyard and Nantucket Island (WHOI 2006). However, there exists no continuous water quality monitoring that is geographically comprehensive for the area.

In recent years there has been growing concern by the local community on Cape Cod that water quality in Nantucket Sound may be having a detrimental effect on marine resources. To date there have been numerous encounters by fishers with nuisance algae in Nantucket Sound as well as declines in fish catch that may be indicative of nutrient loading and eutrophication. However, water quality data to support the claim that water pollution is the cause of these problems are sorely lacking.

In the past, Nantucket Sound was generally viewed as being relatively un-polluted compared to other ecosystems previously mentioned (personal comm. Barb Block 2006). However, it is important to conduct water quality monitoring in this area to ensure that it does not meet the eutrophic fate of other large coastal systems such as Long Island Sound, the Mississippi “Dead Zone” and Chesapeake Bay. Granted Nantucket Sound is different from these examples in terms of stratification and tidal exchange, it does not necessarily exclude the Sound from the harmful effects of nutrient loading and eutrophication.

In order to protect the valuable resources of the Sound and understand its environmental status, it will be necessary to conduct an extensive water quality monitoring study as has been implemented in other areas such as the northern Gulf of Mexico and Chesapeake Bay. Important baseline data is needed to determine what the present concentrations of nutrients and dissolved oxygen are throughout Nantucket Sound. By conducting a comprehensive water quality monitoring project we will be able to determine if the Sound is being threatened by eutrophication and if so, take necessary steps to ensure the protection of its resources.
Cape Cod Commercial Hook Fishermens’s Association

The Cape Cod Commercial Hook Fishermen’s Association (CCCHFA) - a non-profit organization dedicated to promoting sustainable fisheries - is interested in enlisting the services of local fishermen in a water quality monitoring program. Fishermen are beginning to suspect that poor water quality in the form of nutrient loading may be partially to blame for some depleted stocks as well as nuisance algae obstructing their gear, and they are interested in taking an active role in finding solutions.

During the summer of 2006, I worked with the CCCHFA in developing a water quality monitoring program for Nantucket Sound and determined the feasibility of utilizing the local fishing community as active participants in the monitoring project. The fishermen’s skills, knowledge, vessels and increasing role as stewards of ocean resources suggest they can be important assets in monitoring efforts. Including fishermen in the water quality monitoring process will ultimately foster better communication between fishermen, scientists and managers and help protect the resources of Nantucket Sound.

Methods:

Development of the water quality monitoring program (Appendix I) was based on experiences I had volunteering with the National Park Service at the Cape Cod National Sea Shore laboratory from June – August 2006 on different water quality monitoring projects. From my volunteer experience and speaking with National Park Service scientists and staff I was able to ascertain which water quality constituents to monitor and gained insight into field and laboratory protocol. Professional staff members at NPS provided useful suggestions about how I should develop the monitoring program. In addition, I conducted internet research on other
monitoring programs and was invited to accompany the Nantucket Soundkeeper Alliance on one of their sampling trips to observe their field methods.

In order to determine the feasibility of conducting water quality monitoring from commercial fishers’ vessels, I directly interacted with CCCHFA fishermen on their boats from June – August 2006. I went on a number of fishing trips with different fishermen and through informal conversation elicited their opinions about water quality and attitudes towards using their vessels as platforms for monitoring efforts. In addition I conducted water quality monitoring procedures (collection of surface and bottom waters, measurement of dissolved oxygen, Secchi depth, temperature and salinity) from a fisherman’s vessel.

My conversations with fishermen were very informal, however, from these talks I found that fishermen were in agreement with the following three points:

1. Water quality monitoring is needed in Nantucket Sound.

2. Methods for collecting samples and field data were straightforward and easy to learn.

3. Fishers’ vessels could be used for water quality monitoring.

From all my experiences – volunteering at NPS, interacting with fishers and conducting internet research - I was able to determine the key components to my program including: what constituents to monitor, how to collect water samples and field data, sampling sites, frequency of data collection, and water analysis methods. This information allowed me to construct a field protocol for water quality monitoring in Nantucket Sound (Appendix I).

Challenges:

One of the major challenges facing this project is obtaining financial support. In order to implement the water quality monitoring program a significant amount of funding is needed to

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4 The Nantucket Soundkeeper Alliance is also interested in developing a water quality monitoring program for the Sound. The sampling trip that I went on was a pilot study for their monitoring program. To date they do not have a regular sampling system in place for comprehensive water monitoring.
pay fishers, the National Park Service for laboratory analysis as well as for purchasing monitoring instruments and supplies. An estimated start up budget of approximately $25,000 will be necessary for launching the program and an additional $21,000 will be needed to support monitoring efforts for each consecutive year (Appendix I). Securing grants and other monetary support, as well as budget management, will be of paramount importance for establishing the program.

Another challenge will be developing monitoring schedules for fisher teams. The inconsistent and ever-changing availability of fishers will present a unique challenge for organizing which captains and crew will monitor sites. Fishers’ schedules are affected by a number of circumstances including weather conditions, fish behavior, and vessel mechanical failures and can result in limiting the availability of fishers for monitoring trips.

**Recommendations:**

There are various options for obtaining funding for the monitoring program. CCCHFA has limited funds for supporting cooperative research efforts that come from dues and intensive fundraising. However, most of CCCHFA’s cooperative research projects are funded through obtaining grants through the Northeast Consortium – an organization responsible for administering funds from the National Oceanographic and Atmospheric Administration for cooperative fisheries research in New England. The greatest potential for obtaining financial support for the monitoring program will be through the Northeast Consortium, since over the past seven years CCCHFA has had a successful track record in securing grant monies from them to fund projects.
Other funding alternatives may come from grants and/or through the Environmental Protection Agency which maintains a database listing all available federal funds for a wide range of water quality research topics. Also, private organizations dedicated to environmental protection have been known to give financial support for research in conservation. Companies such as Patagonia – an outdoor clothing and gear outfitter – provide millions of dollars in grant monies to environmental grass roots organizations for a broad range of conservation issues.

Once funds are obtained for the project, budget development will be an important issue. The estimated costs in Appendix I for the initial and consecutive years for monitoring may need to be revised depending on the amount of funds available. A large percentage (approximately 30%) of the total cost for the monitoring program originates from the $35 National Park Service fee for a complete laboratory analysis of one sample. Given that there will be thirty samples per month, laboratory fees for the entire year will cost over $6000. This cost could be significantly reduced if samples were taken to the School of Marine and Atmospheric Science and Technology (SMAST) at the University of Massachusetts, Dartmouth. The cost for processing samples is less expensive\(^5\) and SMAST has an extensive history of providing laboratory and training assistance for local community water quality monitoring programs. However, SMAST is located further from CCCHFA than the National Park Service and may pose greater logistical issues with transporting samples to the lab. Also, CCCHFA has already developed a working relationship with National Park Service staff that is conducive to implementing the water quality monitoring program.

Another possible alternative to reduce the cost of the budget would be to reduce the number of fisher teams conducting water quality monitoring exercises. By cutting the number of

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\(^5\) The current rate for a complete laboratory analysis of nutrients and chlorophyll a and pheophytin is $10 per sample.
teams down to three the program budget would be saving approximately $6000 (which could be used for processing samples at NPS). Reduction of teams may also help the CCCHFA in tracking fishers’ availability and may make scheduling monitoring trips less complicated.

The issue of dealing with the difficulties of organizing fisher teams according to their inconsistent availability can be addressed by having, as mentioned previously, less teams or having additional teams that can be placed on standby in the event one team is not able to conduct monitoring exercises. The CCCHFA staff member responsible for organizing the teams will need to be flexible and adaptable to the changing schedules of fishers and be able to make quick changes to the monitoring schedule. He/she will need to work closely with all fishers to be able to hold each team accountable for monitoring assigned sites.

With regard to fisher field training sessions, if NPS is unable to provide a professional staff member to train fishers, than there are two options I recommend. One alternative is to have a CCCHFA staff member give training sessions to fishers after consulting with NPS on monitoring techniques and methods. A second choice is to have Smast provide training as they have had wide experience in aiding other local water quality monitoring programs. SmaST follows lab and field procedures that are consistent with quality assurance and control with the EPA.

A final recommendation is for CCCHFA to develop a health index score using data obtained from the monitoring program. In order to assess the environmental status of each monitoring site, a health index score similar to the Buzzard’s Bay water quality monitoring program will need to be established (Coalition for Buzzards Bay 2007). Both the Buzzard’s Bay and Pleasant Bay programs can provide assistance with developing the health index score which will provide a tool to gauge the environmental health of the Sound
Conclusion:

Water quality monitoring is needed in Nantucket Sound and fishers from the Cape Cod Commercial Hook Fishermen’s Association are willing to be active participants in this effort. The data collected from this water quality monitoring program will provide coastal managers a tool for assessing compliance with state and federal water quality standards and give fishery scientists important information for addressing declines in fish stocks. A water quality program is needed for Nantucket Sound and this plan lays the framework to implement monitoring efforts.
References


The Coalition for Buzzards Bay. 2007. Available at: http://savebuzzardsbay.org/ourwork/research/bay-health-index.htm


DRAFT

Water Quality Monitoring Plan for the Cape Cod Commercial Hook Fishermen’s Association

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Introduction

A. Background

Nantucket Sound is an area of important biological diversity and is a source of employment, recreation and inspiration for people that visit and live near its shores. In the past, its waters have been viewed as clean and generally un-polluted, however concerns are now rising that the Sound may be experiencing the adverse effects of water pollution. Proliferation of nuisance algae throughout the Sound and declines in fish stocks over the last decade has raised awareness in the general public that Nantucket Sound’s waters may not be as pure as once thought.

Historically, there has been a lack of continuous water quality monitoring in the Sound which has resulted in the absence of important data - information that could be used to assess the Sound’s environmental status and identify the source of its problems. This plan aims to fill the information void by providing a systematic water monitoring program for the Sound that will utilize fishers from the Cape Cod Commercial Hook Fishermen’s Association (CCCHFA) and their vessels as platforms for conducting monitoring efforts.

CCCHFA is a non-profit organization dedicated to promoting sustainable fisheries and is interested in enlisting the services of local fishers in a water quality monitoring program. Fishers have suspected that poor water quality may be playing a role in the presence of nuisance algae and depleted fish stocks in the Sound, and they are interested in taking an active role in the solution. The fishers’ skills, knowledge, vessels and increasing role as stewards of ocean resources suggest they can be important assets in monitoring efforts. Including fishermen in the water quality monitoring process will foster better communication between fishermen, scientists and managers that will ultimately help conserve the resources of the Sound.
B. Objectives

The objectives of the water quality monitoring program include providing data that can be analyzed for policy, regulatory, and educational applications. Federal, state and local management professionals will be given access to all monitoring data. This information will provide resource managers insight into the status of the Sound and will help identify areas of environmental degradation for which mitigation plans can be developed.

Also, establishing a water quality monitoring program for Nantucket Sound will provide baseline data which can be used to evaluate long-term trends in water quality. A baseline will provide the means to assess the environmental status of the Sound and will aid in quantitatively understanding the biological and physical processes which control inputs to receiving waters. The plan will describe water quality parameters that will be measured, monitoring sites and frequency, fisher teams, field protocol, and quality control. Furthermore, estimated costs for the project will be presented and responsibility for data management and analysis will be addressed. This plan aims to provide a basic framework and guidelines for monitoring water quality in Nantucket Sound and is open to further recommendations and revisions.

Data Analysis and Management:

Data analysis will be conducted by the National Park Service at the Cape Cod National Sea Shore laboratory in Truro, MA. NPS will process all samples according to the quality control and assurance guidelines from EPA. Also, NPS will maintain a database which will be shared in conjunction with CCCHFA. CCCHFA will be able to use the data to develop reports (written either by CCCHFA or an outside source) about the environmental status of the Sound, which will provide coastal managers a tool for conserving or restoring the Sound. Reports and data will be made available online on both CCCHFA and NPS websites.
**Water quality parameters**

A. Nutrients

Biological productivity is driven by nutrient availability in addition to light exposure and temperature. Nitrogen and phosphorus are the two most important nutrients for primary production. In marine ecosystems nitrogen is considered to be the limiting nutrient for growth (i.e. nutrient that is in the shortest supply in the system), whereas phosphorus is primarily limiting in freshwater environments (Nixon 1995). However, to a certain degree, both nitrogen and phosphorus are essential for the continued productivity of the system. Studies have shown that when nitrogen levels are very high, phosphorus can become the limiting nutrient in marine systems (Fourquarean and Zieman 1992, Thingstad et al. 1998).

Excessive nutrient loading is being driven mainly by anthropogenic sources (waste water, atmospheric deposition, runoff) which causes an increase in primary production in the form aquatic plant growth. This increased growth reduces water transparency and dissolved oxygen concentrations, thereby changing the nature and composition of existing plant and animal communities.

Since Nantucket Sound is primarily a marine system, focus will concentrate in monitoring for nitrogen. Nitrogen enters and cycles within the marine environment in various forms - some more biologically available than others. For this reason, it will be important to measure a number of forms of nitrogen to obtain an accurate picture of the availability of total nitrogen concentrations in the Sound. Surface and bottom water samples will be collected and analyzed for the following forms of nitrogen as well as other nutrients.

B. Dissolved Inorganic Nitrogen (DIN) and Dissolved Organic Nitrogen (DON)
The three main forms of inorganic nitrogen are nitrite, nitrate and ammonium. Most of the nitrogen that enters coastal waters are in one of these three forms and originates from wastewater, runoff and atmospheric deposition. Ammonium, nitrite and nitrate are biologically available forms of nitrogen and stimulate the growth of algae and phytoplankton (Novotny 2003). High levels of DIN usually indicate that the system is severely overloaded with nitrogen.

Dissolved organic nitrogen is nitrogen incorporated in living tissue and make up complex organic compounds (e.g., urea and amino acids) that are released by living organisms and decaying organic matter. DON levels are generally greater in eutrophic waters reflecting the higher amounts of living material.

Samples for analysis of dissolved nutrients will be collected and field filtered by fishers and the filtrate transported to the laboratory for analysis. Concentrations will be reported as milligrams of nitrogen per liter (mg N/L) for both inorganic and organic nitrogen.

C. Particulate Organic Carbon (POC) and Particulate Organic Nitrogen (PON)

POC is carbon from particulate matter larger than 0.2 um in diameter (Microbial Life 2007). It is an additional measure of the quantity of tissue, living and dead, present in the water column. PON is nitrogen from particulate matter that is also greater than 0.2 um in diameter. It is manifested in the form of living and dead tissue - primarily phytoplankton, zooplankton, algae and larger aquatic organisms. Eutrophic waters will generally have higher levels of PON than less nutrient enriched waters.

PON and POC will be reported as milligrams of nitrogen and carbon respectively, per liter (mg/L). Samples for measurement of particulate constituents will be collected by fishers and transported to the laboratory for analysis.
D. Orthophosphate (PO$_4$)

Although phosphate is not considered a limiting nutrient in the marine environment, determining its levels can provide an indication of the influence of freshwater inputs to the systems. Orthophosphate will be determined from the same filtrate fraction as the DIN components and will be reported in milligrams of Phosphorus per liter (mg/L).

E. Chlorophyll a and Pheophytin

Measuring plant pigments (chlorophyll a and its breakdown product pheophytin) gives an estimate of the algal biomass present in the water sample. Chlorophyll a is the principal photosynthetic pigment found in most phytoplankton and algae. Variations in algal populations will occur throughout the year depending on temperature, light levels and nutrient availability. Measuring chlorophyll a levels provides an indication of the response of algal populations to the available nutrients and provides correlations to water transparency, and oxygen levels. Plant pigments will be measured from samples collected by fishers. Collected water samples will be brought to the laboratory for analysis. Chlorophyll-a and pheophytin concentrations will be reported as micrograms of pigment per liter (ug/L).

F. Salinity

Salinity is a measurement of the amount of dissolved salts in a given volume of water and is reported in units of parts per thousand (ppt). Salinity varies throughout the tidal cycle and with changes in freshwater inputs through groundwater, rainfall and surface discharges. Also, salinity can cause density stratification where more dense, highly saline waters are situated below less dense freshwater. Stratification frequently results in bottom waters experiencing lower dissolved oxygen levels than compared to surface water. Salinity will be determined in the field using a refractometer and values will be used for calibrating the dissolved oxygen meter.
G. Temperature

Temperature is an important measurement as it plays a major role in controlling the amount of dissolved oxygen that water can hold. All factors equal, warmer waters will have a lower potential dissolved oxygen level than cooler waters since warm waters tend to support more biological activity that depresses oxygen levels. Measuring surface and bottom temperatures will provide additional indicators for the presence and degree of stratification that may be occurring. Temperature, will be measured in degrees Celsius (°C) using a thermistor that is integrated as part of the dissolved oxygen meter.

H. Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen molecules dissolved per given volume of water. Additionally, DO levels can be expressed as percent saturation that determines how much oxygen water can hold at a given temperature and salinity. Specific concentrations of DO are required for the growth and survival of most aquatic organisms. Low DO levels frequently reflect increased biological activity (respiration). Replenishment of oxygen generally occurs through two mechanisms, exchange between the atmosphere and water interface and photosynthesis. As a result from photosynthesis, oxygen levels are lowest in the early morning and are further impaired on calm, cloudy days.

Nutrient loading and eutrophication can lead to depletion of oxygen concentrations in the marine environment which can pose negative consequences for the ecology of these systems. Eutrophication of water bodies can cause increased growth of plant species such as different algal blooms. These increased blooms consequently deplete oxygen levels through the decomposition of dead zooplankton and plants by bacteria (Carpenter et al. 1998).
Most aquatic organisms function well when DO levels are above 5 mg/L. Many organisms, especially non-motile species (i.e. shellfish) will begin to experience stress when DO levels decrease to 3-5 mg/L (McClellan 2006). Marine waters experiencing hypoxia have dissolved oxygen levels between 0.5 – 3 mg/L and will result in species leaving the area or dying if non-motile (McClellan 2006). Anoxic conditions are characterized as levels below 0.5 mg/L and will cause the death of any organism that requires oxygen (McClellan 2006).

The extent of low DO conditions is also important. Many species are able to tolerate short periods of hypoxic conditions without ill effect, however, if these periods are prolonged or occur frequently the effects on organisms become more severe. Oxygen concentrations will be recorded in units of mg/L and % saturation using YSI Model 550 DO meters.

I. Turbidity

Turbidity is a measure of water clarity and light penetrating ability. It is affected by the amount of suspended particulate matter in the water. Suspended material may be inorganic sediment and/or biological (phytoplankton and zooplankton). Highly turbid waters (low transparency) will adversely impact submerged aquatic vegetation by reducing the amount of light available for growth and photosynthesis. This can subsequently trigger effects on other organisms by reducing DO levels. Transparency can be affected by natural mechanisms such as runoff from terrestrial systems and storm events that cause the re-suspension of bottom sediments. Transparency in marine systems is frequently affected by the growth of phytoplankton in response to nutrient availability. Phytoplankton blooms result from over-stimulation of the system by excessive nutrient input and can reduce transparency to near zero on the bottom with significant impacts on aquatic organisms and vegetation.
Transparency will be determined by using a Secchi disk for measuring the depth at which
the disk is no longer visible. The shallower the depth the greater the amount of suspended
material in the water will be. Secchi depth ranges can be from <1 m in highly eutrophic
embayments to >4 m in offshore coastal waters.

**Monitoring Sites and Frequency:**

Sampling locations were chosen to further the objective of providing comprehensive
baseline data on water quality conditions throughout the Sound. Fifteen sites were chosen using
the following criteria:

- representation of the geographic diversity of the Sound
- potential for having excessive nutrient levels

Figure 1 and Table 1 on the following page provide details as to where each monitoring site is
located.

![Figure 1. Proposed sites for the Nantucket Sound water quality monitoring program.](image-url)
<table>
<thead>
<tr>
<th>Site</th>
<th>Coordinates</th>
<th>Site</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS-1</td>
<td>41°30′20″ N 70°32′0″ W</td>
<td>NS-9</td>
<td>41°24′30″ N 70°14′20″ W</td>
</tr>
<tr>
<td>NS-2</td>
<td>41°26′10″ N 70°30′20″ W</td>
<td>NS-10</td>
<td>41°20′40″ N 70°13′50″ W</td>
</tr>
<tr>
<td>NS-3</td>
<td>41°29′0″ N 70°27′30″ W</td>
<td>NS-11</td>
<td>41°29′0″ N 70°11′0″ W</td>
</tr>
<tr>
<td>NS-4</td>
<td>41°35′30″ N 70°26′10″ W</td>
<td>NS-12</td>
<td>41°38′40″ N 70°07′15″ W</td>
</tr>
<tr>
<td>NS-5</td>
<td>41°21′50″ N 70°22′50″ W</td>
<td>NS-13</td>
<td>41°20′50″ N 70°07′0″ W</td>
</tr>
<tr>
<td>NS-6</td>
<td>41°29′0″ N 70°19′0″ W</td>
<td>NS-14</td>
<td>41°29′0″ N 70°04′0″ W</td>
</tr>
<tr>
<td>NS-7</td>
<td>41°36′30″ N 70°17′0″ W</td>
<td>NS-15</td>
<td>41°39′0″ N 69°59′40″ W</td>
</tr>
<tr>
<td>NS-8</td>
<td>41°34′0″ N 70°14′20″ W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Latitude and longitude for monitoring sites.

Monitoring of these sites and collecting water samples will occur once a month from May through October during the morning hours (6-9AM) to take into account “worst case” data for dissolved oxygen. The three hour time frame will enhance comparability of data for Nantucket Sound from other monitoring programs. Sampling dates will be based on tide stages and will be scheduled approximately near mid-tide during an ebb tide.

For each site samples will be collected, field filtered for dissolved nutrients, and stored on ice in coolers for future laboratory nutrient analysis. On site measurements will include salinity, depth, temperature, dissolved oxygen, turbidity and field observations (wind speed and direction, weather and sea conditions, etc.).

**Fisher Monitoring Teams:**

Five teams of fishers, consisting of a captain and crew (generally one or two people) will be organized to conduct monitoring and collection exercises – each team being responsible for three different sites (Table 2). The CCCHFA research director or appointed staff member will be responsible for selecting each team. Selection will be an organic process that involves dealing...
with the changing schedules and availability of the captains. Priority will be given to captains who have paid their annual membership dues to the CCCHFA.

<table>
<thead>
<tr>
<th>Team</th>
<th>Monitoring Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,2,3</td>
</tr>
<tr>
<td>B</td>
<td>4,6,8</td>
</tr>
<tr>
<td>C</td>
<td>7,12,15</td>
</tr>
<tr>
<td>D</td>
<td>9,11,14</td>
</tr>
<tr>
<td>E</td>
<td>5,10,13</td>
</tr>
</tbody>
</table>

Table 2.

Workshop seminars will be held by a trained National Park Service professional(s) to educate fishers on water sampling methods and data collection techniques. Ideally, seminars should only require one day of training, however, additional days may be needed and incorporated into the seminar schedule as seen fit by the workshop instructor. Specifically, the workshop will first cover an overview of the goals and objectives of the program, uses of water quality data and the importance of timely and accurate data. Seminars will focus in detail on each activity required in the field, the use of field kits and instruments, sample handling, filtration technique and routine care and maintenance of equipment. NPS trainers will accompany fishers on initial monitoring trips to provide guidance and conduct skill assessment.

**Monitoring Protocol:**

A. Pre-monitoring preparation:

Before leaving port each team must ensure that all supplies and instruments are on board the vessel. The CCCHFA will hold supply kits containing all instruments required for monitoring. Data will be recorded on forms prepared by the CCCHFA and will be included in all water quality monitoring kits. Templates for these forms are provided in Appendix II. Captains will be responsible for checking out supplies from a CCCHFA staff member. At the
end of each monitoring trip all supplies and instruments will be returned to the CCCHFA. All
monitoring supplies and instruments are listed in Tables 3 and 4. All fisher teams will be
responsible for monitoring their respective sites and collecting samples and field data as outlined
below. Instruction for all techniques used in the field will be taught prior to the deployment of
field teams by a trained National Park Service professional.

B. Field Procedures

The order for collecting samples and data must be followed in the sequence detailed on
the following page.

i. Field observations

Once the site has been reached field observations are recorded on the data form provided
with the monitoring kits. Observations to be noted at this time are weather conditions, wind
speed and direction, depth and sea conditions (recorded according to the Beaufort scale).

ii. Turbidity

As mentioned in the water quality parameters section, turbidity will be measured using a
Secchi disk. The disk will slowly be lowered into the water until it is no longer visible. The
depth of visibility loss is recorded to the nearest 0.1 meter. If currents cause the disk to make an
angle with the boat, an approximate reading must be taken.

Collecting surface water

Surface water salinity will be measured in situ with a refractometer. A hand grab using a
HDPE bottle will be used to obtain surface water. A drop of water will be placed on the glass
slide of the refractometer and pressed down against with the cover. Salinity will be read from
the viewer and recorded. This value will be entered into the YSI for calibration purposes. After
the YSI has been calibrated the YSI probe will be lowered approximately 0.5 meters below the
surface. Readings for temperature and dissolved oxygen will be recorded once values have stabilized. Additionally, temperature can be recorded from ship instrumentation for comparison with YSI readings.

Water samples for nutrient analysis will be obtained from deployment of the Niskin sampler. For surface waters the Niskin sampler will be deployed to collect water at 0.5 meters below the surface. For analysis of chlorophyll a, pheophytin and particulate organics, the collected water sample will be transferred to an acid clean high density polyethylene (HDPE) 1 liter brown bottle. The bottle will be completely filled with the water sample and be labeled to indicate surface sample, site number, date and “CHL/POC” to distinguish it from the dissolved nutrients. Procedures for collecting sample for dissolved nutrients involve using a 30 mL syringe with a 0.2 um filter attached and filtering a total of 60 mL into a 100 mL HDPE clear bottle and stored on ice in the dark.

iv. Collecting bottom water

Salinity will be measured using a refractometer. However, unlike surface waters, the drop of water applied to the refractometer will come from the water obtained by the Niskin sampler. The salinity value will be recorded and will be used to calibrate the YSI.

Once the YSI has been calibrated for bottom water salinity, temperature and dissolved oxygen will be measured directly from the water in the Niskin sampler. This technique is likely to produce inaccurate results, however, it is the best option given the limitations of measuring bottom temperature and dissolved oxygen in situ.

Procedures for bottom water nutrients will follow the same order as surface waters after salinity, temperature, and dissolved oxygen are measured. The Niskin sampler will be deployed to collect water 0.5 meters from the bottom.
The following tables summarize the sampling methods described above. The tables were adapted from the Pleasant Bay Citizen Water Quality Monitoring Program to fit the needs of this project.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sampling</th>
<th>Sample</th>
<th>Sample</th>
<th>Max.</th>
<th>Field</th>
<th>Preservatio n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Equipment</td>
<td>Container</td>
<td>Volume</td>
<td>Holding</td>
<td>Processing</td>
<td>Time</td>
</tr>
<tr>
<td>Temperature</td>
<td>YSI 550</td>
<td>None (surface water), in-situ</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Meter</td>
<td>measurement, bottom water temp taken from Niskin sampler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>YSI 550</td>
<td>None, in-situ</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Meter</td>
<td>Measurement (surface water), bottom water DO taken from Niskin sampler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Salinity</td>
<td>Refractometer</td>
<td>None, in situ</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measurement</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom Salinity</td>
<td>Niskin sampler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secchi/Total Depth</td>
<td>Secchi Tape</td>
<td>None, in-situ</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measurement</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Summary of methods for physical parameters and dissolved oxygen.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sampling</th>
<th>Sample</th>
<th>Sample Max.</th>
<th>Sample Field Processing</th>
<th>Preservatio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Equipment</td>
<td>Container</td>
<td>Volume</td>
<td>Holding Time</td>
<td></td>
</tr>
<tr>
<td>Nitrate &amp; Nitrite</td>
<td>Niskin Sampler</td>
<td>High Density</td>
<td>60 ml</td>
<td>48 hrs</td>
<td>0.2um membrane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyethylene</td>
<td></td>
<td></td>
<td>Filtration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>acid-washed</td>
<td></td>
<td></td>
<td>transport to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clear bottle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved Ammonium</td>
<td>Niskin Sampler</td>
<td>HDPE, acid washed</td>
<td>60 ml</td>
<td>12-24 hrs</td>
<td>0.2um membrane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clear bottle</td>
<td></td>
<td></td>
<td>Filtration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>transport to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DON</td>
<td>Niskin Sampler</td>
<td>HDPE, acid washed</td>
<td>60 ml</td>
<td>12-24 hrs</td>
<td>0.2um membrane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clear bottle</td>
<td></td>
<td></td>
<td>Filtration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>transport to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>Niskin Sampler</td>
<td>HDPE, acid washed</td>
<td>60 ml</td>
<td>12-24 hrs</td>
<td>0.2um membrane</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clear bottle</td>
<td></td>
<td></td>
<td>Filtration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>transport to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POC/PON</td>
<td>Niskin Sampler</td>
<td>HDPE, acid washed</td>
<td>1000 ml</td>
<td>24 hrs</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brown bottle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>transport to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorophyll-a &amp;</td>
<td>Niskin Sampler</td>
<td>HDPE, acid washed</td>
<td>1000 ml</td>
<td>24 hrs</td>
<td>None</td>
</tr>
<tr>
<td>Pheophytin-a</td>
<td></td>
<td>Brown bottle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Summary of methods for nutrients and plant pigments.

C. Transporting samples to the National Park Service Laboratory

Samples and data will be picked up by National Park Service staff at a designated time from the dock and transported to the laboratory in Truro. For the first two monitoring trips NPS staff will already be aboard the monitoring vessels and will be able to return directly to the lab.
with all data and samples. Depending on the circumstances\textsuperscript{6} transporting samples and data may not be restricted to pick up by NPS staff and may involve fishers having to bring samples and data to the laboratory themselves. The CCCHFA staff member responsible for organizing fisher teams will need to maintain a degree of flexibility in coordinating pick up and transportation of samples and data to the NPS laboratory.

**Quality Assurance/Control**

Quality assurance and control of the data will follow procedures for the National Park Service which is consistent with standards of the U.S. Environmental Protection Agency (EPA). All training of fishers will be conducted by National Park Service (NPS) staff and fishers will be accompanied by training instructors on initial monitoring trips (first two trips) to assure consistency in methods. All NPS laboratory analyses are performed using quality control guidelines designed by EPA.

**Estimated Costs:**

The initial costs for the first year of implementing the program as well as the cost of monitoring for each consecutive year is given on the next page (Table 5). Compensation for fishers is based on the standard rate paid by CCCHFA for cooperative research involving a time commitment less than six hours (fishers will likely spend a maximum of three hours in the field). This rate is slightly variable due to fuel costs. This budget reflects the necessary expenditures for the program; however, the total cost of the first year may be reduced if NPS is able to provide some support in the form of limited instruments and supplies.

\textsuperscript{6} Circumstances may include but are not limited to NPS not being able to send someone to pick up samples or fishers being late to the dock for the initial pick up time.
<table>
<thead>
<tr>
<th>Expenditure</th>
<th>Cost</th>
<th>Number of items</th>
<th>Total</th>
<th>First year cost (May-Oct.)</th>
<th>Consecutive annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisher compensation</td>
<td>$500 (per trip)</td>
<td>5 teams</td>
<td>$2500</td>
<td>$15,000</td>
<td>$15000</td>
</tr>
<tr>
<td>YSI 550</td>
<td>$725</td>
<td>5</td>
<td>$3625</td>
<td>$3625</td>
<td>-</td>
</tr>
<tr>
<td>Secchi disk</td>
<td>$25</td>
<td>5</td>
<td>$125</td>
<td>$125</td>
<td>-</td>
</tr>
<tr>
<td>Refractometer</td>
<td>$30</td>
<td>5</td>
<td>$150</td>
<td>$150</td>
<td>-</td>
</tr>
<tr>
<td>HDPE bottles (1 liter)</td>
<td>$7</td>
<td>15</td>
<td>$105</td>
<td>$105</td>
<td>-</td>
</tr>
<tr>
<td>HDPE bottles (100 mL)</td>
<td>$2</td>
<td>15</td>
<td>$30</td>
<td>$30</td>
<td>-</td>
</tr>
<tr>
<td>Coolers (5)</td>
<td>$25</td>
<td>5</td>
<td>$125</td>
<td>$125</td>
<td>-</td>
</tr>
<tr>
<td>Ice</td>
<td>$3</td>
<td>5</td>
<td>$15</td>
<td>$90</td>
<td>$90</td>
</tr>
<tr>
<td>NPS analysis (1 sample)</td>
<td>$35</td>
<td>30</td>
<td>$1050</td>
<td>$6300</td>
<td>$6300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TOTAL:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$25550</td>
<td>$21390</td>
</tr>
</tbody>
</table>

Table 5. Estimated costs for the water quality monitoring project.
References


APPENDIX II

Template for data recording adapted from the Buzzards Bay monitoring program

**General Conditions**

<table>
<thead>
<tr>
<th>Station ID.</th>
<th>Sample Date</th>
<th>Fisher Team</th>
</tr>
</thead>
</table>

Beaufort Scale (Force #0 - 12)

Weather Conditions: (choose one)

<table>
<thead>
<tr>
<th></th>
<th>1 Cloudless</th>
<th>2 Pt. Cloudy</th>
<th>3 Overcast</th>
<th>4 Fog/Haze</th>
<th>5 Drizzle</th>
<th>6 Intermit. Rain</th>
<th>7 Rain</th>
<th>8 Snow</th>
</tr>
</thead>
</table>

24 hour Precipitation (choose one)

<table>
<thead>
<tr>
<th></th>
<th>1 None</th>
<th>2 Light</th>
<th>3 Heavy</th>
</tr>
</thead>
</table>

Wind direction (ie. SE, NW)

(meter) Secchi Disk depth

(meter) Total water depth at station

Other observations

---

**Depth Specific Parameters**

<table>
<thead>
<tr>
<th>Collection Time (6-9am)</th>
<th>SURFACE 0.5 m below surface</th>
<th>BOTTOM 0.5 m from bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>meters</td>
<td>meters</td>
</tr>
<tr>
<td>Sample collection depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound Water Temperature</td>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>Salinity</td>
<td>ppt</td>
<td>ppt</td>
</tr>
</tbody>
</table>